4TU. CENTRE FOR ENGINEERING EDUCATION

Anticipating the New Educational Challenges for Universities

Emiel van Puffelen & Perry den Brok

WAGENINGEN UNIVERSITY & RESEARCH

Contents

1. Introduction

In recent years, higher education has started to face a combination of challenges: economic uncertainty, accountability, globalization and emerging technologies that are daunting to learn and intimidating to implement (Waller et al. 2019). Universities are confronted with a world in which continuous change has become the new normal, characterised by Volatility, Uncertainty, Complexity and Ambiguity (VUCA) (Kamp 2020). From 2020 onwards, with the coronavirus pandemic, geopolitical developments and new options for AI text generation, the changes seem to become even more unexpected, quick and drastic. The changes in our VUCA world affect the required competencies of all university graduates, especially engineering graduates, as their jobs deal with the changes in the world. In addition, universities and their educational environments are directly influenced by the changes as well. Several scholars suggest that different types of drivers fuel change and innovation at general and engineering universities (Den Brok 2018), (Kamp 2020), (Lemmens 2015). In the present study, following these scholars, we distinguish between the following types of change drivers:

- **Trends demanding different graduate profiles**

  Trends like rising population and urbanization, globalisation and digitalisation, geopolitical shifts and the need to reach Sustainable Development Goals, demand for change in graduate profiles.

- **Need for different/new competencies.**

  Graduates need to contribute to solutions for the grand challenges of the world, which require new types of competencies, like being able to work in complex, uncertain, dynamic, and multifaceted work environments.

- **Developments in the population of learners.**

  The new students are often referred to as “Generation Z” and show characteristics such as more visually than verbally oriented, more inclined to ‘try and see’ than to ‘sit and listen’, more used to facilitators than to teachers, more used to flexibility than to job security, more used to collaborate than to be commanded, more used to learner centrism and the open book world, and more used to devices than to paper. And at some universities, the student population becomes more diverse in cultural values, language proficiency, religion, economic background, and prior knowledge.

- **New options for the design of learning.**

  Learning management systems and blended learning offer universities various teaching and learning activities (TLAs). Students prefer different forms of TLAs, such as face-to-face or online. The challenge is to use well-designed TLA combinations geared towards the needs of Generation Z students, offer flexible learning paths, activate learning, and stimulate student-centred learning.

- **Change within science and research.**

  Science developments can affect education; examples are the focus on nanotechnology, artificial intelligence, increasing use of robots, convergence of disciplines – such as computing and communication -and the link between science and ethics. This demands more diverse specialized experts. Also, complex problems require graduates to work in interdisciplinary teams, where organisations, like companies and governmental or civic agencies, collaborate. Science is becoming a 'contested' domain, with actors next to scientists. Citizen science is a new trend, with citizens involved in the collection of research data and analysis – think of insect and bird counting days.

- **New societal roles for universities**

  Opportunities like Impact-focused education need to be addressed in university strategies. Important aspects are the balance between societal roles and interaction with employers and industry, criticism by anti-science and anti-education populism and options and threads to the university role in continuous/lifetime education.

The challenges of the VUCA world require universities to innovate (Waller et al. 2019). This raises the question of which innovations can be an answer to which drivers/developments? This paper reviews the literature on each driver's impact on universities and analyses the combined result. It uses an underpinned conceptual approach to answer the following research questions:

- **Which trends are mentioned in the literature for each type of driver that requires universities to innovate in their education?**

- **Which changes are proposed for universities in response to the drivers/changes?**

2. Methods

We performed a thematic literature review on the effects of the change drivers on university education. Searches were done on two research-focused databases containing articles in this field: Scopus and SSCI. The searches were limited to English articles published from 2017 onwards with ("higher education" OR universit*) in the title. Within those limits, search words were used to scan titles. The search words were derived from the six change drivers, and general educational change search words were added, leading to the following list:

future trend*, future competenc*, future graduates, learning goals, "types of students", student characterisation, ICT in education, chang* science, future transition, vision education, "future education", "future skills", societal, world trends, "innovation of education", "educational ecosystem*"

Only one of the search words was required for a result to show up: the search words were separated with "OR". The results of both database searches were imported into a reference manager database, and the complete set was undoubled and stored. A copy of that base database was created from which irrelevant records were removed by studying papers' titles, abstracts and content. The exclusion criteria were topics not relevant to the subjects discussed in the introduction and articles that were too specific for one institute, country, or study program without options for broader use.

Kamp (2020), Lemmens (2015), and Den Brok (2018) see that future world challenges require answers from new types of engineers. To address that in the next step, articles focussing on that were added using the publication website of the 4TU.Centre for Engineering Education (4TU.CEE 2023), which focuses on that subject. Key papers referenced in the search results were also added.
After undoubling, removing irrelevant records and adding the key papers, 60 articles remained, as shown in Table 1.

Table 1: the number of papers found and selected in each step

Step	Number of papers
Scopus search	286
SSCI search	80
Both searches combined and undoubled	319
Remaining after removing irrelevant papers	32
Total after adding key papers	60

After that, as shown in the results section, each paper was grouped according to the change drivers. Within most drivers, the papers showed similarity in subgroups, which we labelled as subdrivers. The results were discussed at the subdriver and driver levels, and conclusions on the design needed for the educational setup of universities in the following decades were formulated.

3. Results

The 60 resulting papers were grouped into the change drivers. Within those groups, the papers showed a focus on a few common subjects, labelled as subdrivers in Table 2 below. The only exception is the change driver, "Change within science and research", which had just one paper reporting education impact. The articles used to make the driver list and those of the first driver focused on future vision and contained policy papers. Some papers are relevant for more than one (sub)driver, which explains the larger sum than 60.

Table 2: drivers and subdrivers found, with the number of articles in them.

Driver	Subdrivers	papers
Trends demanding different graduate profiles		11
	Rising population and urbanisation	3
	Societal trends	1
	Change due to geopolitical shifts	3
	Reaching Sustainable Development Goals	4
Need for different/new competencies		22
	T shape skills	6
	Development of the T shape skills	5
	Sustainability Skills	6
	Participating in solving wicked problems	4
	Well-being and life skills	3
Developments in the population of learners		3
	Sense of belonging	2
	More diversity among students	1
New options for design of learning		18
	New curriculum design	3
	Increasing role of ICT and digital resources	3
	Student-Centred Learning	9
	Boundary crossing	2
	Alternative Credentials	1
	Team role of teachers	2
Change within science and research		1
New societal roles for universities		18
	Development of societal roles of universities	3
	Impact-focused education	4
	Societal roles and interaction with employers and industry	4
	Lifelong learning: upskilling & relearning	2
	Influence national higher education policy	4

Trends demanding different graduate profiles

The articles showed four types of global trends which have consequences for future graduates, as discussed below.

Rising population and urbanisation

In the 21st century, we face major global challenges. Humanity overconsumes the planet's natural resources; malnutrition continues worldwide, urban centres become overpopulated, and the climate changes rapidly. Globally, 800 million people suffer from chronic hunger and about two billion from malnutrition. In contrast, obesity and related illnesses dominate the Western world. In addition, we are increasingly confronted with the global spread of infectious diseases. (Wageningen University & Research, 2019). In 2050, 9.7 billion people will inhabit the earth (United Nations Department of Economic Social Affairs 2022). At that time, 68 per cent of that population will live in urban areas (United Nations 2019). These overpopulated urban centres are now already confronted with degraded air quality, reduced water availability and green space, problems with waste removal, and food and energy supply. Rising sea levels will strongly add to these problems in many highly populated areas, and extreme weather is increasingly causing severe problems worldwide.

Societal trends

Adding to this are three societal trends that, according to Kamp (2016), have made our world become VUCA:

> Globalisation and digitalisation can blur boundaries – between nations, disciplines, and professions, between academia and industry, and between applied science and engineering.

> The horizontalization of the socio-economic world transfers power to consumers and end-users.

> The blending of technical, economic and societal structures leads to business and innovation approaches where technology-driven innovation is replaced by client- and consumer-driven approaches.

Change due to geopolitical shifts

From 2022 onwards, geopolitical shifts resulted in even quicker change. And that contributes to global challenges which have become more urgent, such as climate change, healthy food and living, biodiversity, nitrogen crisis, circularity, and competing claims for space (Wageningen University & Research 2022). In addition to this, Graham (2018) sees a tilting of the global axis of engineering education

leadership from north to south and from high-income countries to emerging economic powerhouses in Asia and South America. Such a shift can also be seen in digital platforms: multisided markets that facilitate value-creating exchanges among users, such as social media, e-commerce, software, application downloads, search, email, and cloud services, according to Mueller and Farhat (2022). They show that the United States and China headquarters all but one of the world's top 20 platforms. Their analysis is that geopolitical choices can lead to a digital economy split between those countries, causing diverging standards and rules, diminished trust, and barriers to market entry and technology transfer. Given the global character of this, higher education graduates must be able to operate between and on both sides of that split. In general, geopolitical shifts pose challenges for future workers.

Reaching the Sustainable Development Goals (SDG)

These trends are emerging in a world that needs improvement to reach the SDG formulated by United Nations (2015). No poverty, zero hunger, good health and well-being for people, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate change, ensuring life below water and on land, peace justice and strong institutions. Technology dimensions of such goals include, amongst others: make solar energy economical, manage the nitrogen cycle, improve urban infrastructure, engineer better medicines, prevent nuclear terror, secure cyberspace and advance personalized learning (NAE 2017). Kamp (2019) states that engineers will play a key role in tackling these challenges and delivering on the SDG. Likewise, Pelletier et al. (2022) see environmental and sustainability goals as important future trends for education.

Need for different/new competencies

These trends have consequences for the competencies required of future graduates. The articles found on the consequences showed five subgroups, as discussed below.

T shape skills

Hüsing et al. (2020) see strong effects of digitalisation on industry. They analysed digitalisation trends and concluded that future workers in industry need T-shaped skills as defined by Michigan-state-University (2022). The "deep" (vertical) part has at least one discipline and also at least one system. The broad/ horizontal skills are summarised as "Boundary crossing competencies". This model is for all workers. Kamp (2020) gives details for technical university graduates. He states that a successful career will depend on mastering literacies (technical, data and human) and, to a larger extent, on non-cognitive capacities such as consciousness, self-discipline,

grit, the ability to face challenges and overcome failure, and social skills. These are higher-order mental skills, personal mindsets and ways of thinking/beliefs about the world. They allow students to look beyond short-term concerns to longer-term or higher-order goals and help to overcome challenges and setbacks in their pursuit of these goals. He sees multiple important mindsets: critical thinking, holistic and systems thinking, entrepreneurial thinking, interdisciplinary thinking, cultural agility, value learning over knowing, design thinking, the use of a data-driven approach, coalition building, taking the lead and playing to one's strengths, dissatisfaction with the status quo, a willingness to take risks and learn from failures, or simply a "getting things done" attitude. Lemmens (2015) also sees a need for T shape skills: combining a firm disciplinary basis with skills like collaboration, communication, information and ICT literacy, social and cross-cultural skills, creativity, innovation, critical thinking, decision making, flexible problem solving, adaptability, openness, learning to learn and entrepreneurial skills. He adds professional skills: the ability to communicate, collaborate, reflect, plan and organize, and deal with information. These skills are related: Donoso-González, Pedraza-Navarro, and Palferro-Fernández (2022) advise that entrepreneurship training should improve personal competence like leadership, creativity, autonomy and initiative. McPhillips and Licznerska (2021) point to the importance of competencies to accelerate the inflow and outflow of knowledge: creativity, entrepreneurship, and cooperation.

Development of these T shape skills

There are many options for developing T-shaped skills. Geertshuis, Wass, and Liu (2022) state that to develop future-ready generic graduate capabilities, students need to 1) be enthused to develop personally relevant generic capabilities, 2) have opportunities to explore by intellectually and emotionally connecting learning to processes, topics and situations, 3) develop by purposefully extending their capabilities within varied and progressively more complex contexts, and 4) have opportunities to exhibit their capabilities. Green, Hertzman, and Banderlipe (2021) demonstrate that a university can play a major role in future-proofing the workforce by offering interdisciplinary and multidisciplinary programs, learner-centred pedagogy and activities, and expanded lifelong learning opportunities among graduates and society. Bezanilla, Galindo-Domínguez, and Poblete (2021) found that teachers consider teaching critical thinking at university important, mainly for students to become good professionals in a complex world. Islam and Stamp (2020) see the importance of Global, International, and Intercultural (GII) competencies. Acquiring these competencies requires GII learning opportunities while achieving academic goals. Students, faculty members, and support staff must adopt different cultural perspectives and practices to multiculturalism. Van Puffelen and van Oppen (2020) give an example of aligned policy, activities, support, and training needed for that.

Sustainability Skills

Žalėnienė and Pereira (2021) concluded that "Higher education institutions have a great responsibility to form future sustainability leaders and support the SDGs targets implementation. Higher education establishes the mindset of adult people and is considered a "changing agent" towards sustainability development". Riuttanen et al. (2021) found that basic academic competencies were more familiar than sustainability competencies. That might be because sustainability competencies have not yet been included in curricula for long. Stephens, Palchak, and Reese (2017) found a large variation in how universities apply financial decisions towards their sustainability commitment. They also found that the impact of universities' investments is inconsequential toward the change required to deal with the world's most complex problems. Besides priority, the question is how to foster sustainability skills. Gáspár, Hideg, and Köves (2021) show a course approach to raise awareness and induce the feeling of responsibility for the future by offering the students concepts and methods to become active and reflective citizens. Nölting et al. (2020) suggest sustainability transfer using a mix of exploratory workshops, expert interviews, and a case study of transfer in teaching. They define sustainability transfer as practitioner–university partnerships that strive for sustainable development in society and formulate characteristics of sustainability transfer. Wals (2015) sees sustainability as a wicked problem that, in a sense, cannot be taught. At best, teachers can create environments conducive to exploring sustainability issues around climate change, poverty, food security, biodiversity, etc. As such, teaching sustainability is an educational design challenge with a need for a didactical orientation that enables learners to grapple with wicked problems.

Participating in solving wicked problems

This all shows that graduates will face many problems. Wals (2015) and Fox (2018) distinguish between simple, complex, and wicked problems. Simple problems have predictable, straightforward solutions. Complex problems are less clear but can be resolved over time. They contain many familiar elements, but they also contain hidden, non-linear, and inter-operating elements. Many problems are without precedent and have no proven recipes that can guarantee a good solution. According to Schiefloe (2021), that type of problem can be labelled "wicked". Rittel and Webber (1973) defined wicked problems using ten characteristics.

For a recent major problem, Schiefloe (2021) sees relevance of five of those characteristics:

1. There is no definitive formulation of a wicked problem
2. Solutions to wicked problems are not true-or-false but good-or-bad
3. There is no immediate and no ultimate test of a solution to a wicked problem
4. Every solution to a wicked problem is a “one-shot operation”; because there is no opportunity to learn by trial-and-error, every attempt counts significantly
5. Every wicked problem is essentially unique

Many of our world's problems have these characteristics, and our graduates have to participate in solving wicked problems using their T-shaped skills.

Well-being and life skills

Grosemans, Coertjens, and Kyndt (2020) found that the transition from higher education to work increased self-efficacy, learning goals, and performance-approach orientation. Performance-avoidance decreased on average. So it might be better to foster these skills in university education. Gan et al. (2022) found that teaching well-being and life skills provides students valuable personal growth resources. That approach was well-received at their university, and they hope for future benefits by positively impacting skills, behaviours, attitudes, and values. Kleimola and Leppisaari (2022) found that 19 teachers identified reflective competence, self-awareness and self-management, learning literacy, personal agency, self-efficacy, changeability, digital competence, cooperation and communication competence as necessary for the future. They also see the potential of learning analytics as a means to reflect on learning, develop competence, and increase self-awareness of strengths and weaknesses.

Developments in the population of learners

The articles found on this change driver focused on two subgroup topics, as shown below.

Sense of belonging

Moscardini, Strachan, and Vlasova (2022) conclude that the purpose of the university must be re-evaluated to account for the anticipated changes in employment. They suggest that the emphasis should move from savoir-faire (teaching how to make things) to savoir vivre (how to live one’s life with a different employment pattern). The university will be seen as a means to create a social network of friends and

colleagues, to generate respect, self-esteem, and self-efficacy from doing something one enjoys, a sense of being needed and a meaning to life in being a part of something larger than oneself. Pedler, Willis, and Nieuwoudt (2022) found that university students' sense of belonging is of high importance as it increases students' academic motivation and enjoyment in their studies, which can impact student achievement and reduces the likelihood of students considering leaving university before completing their studies, thus contributing to student retention.

More diversity among students

Mishra and Braun (2021) state that the link of higher education to economic benefits is recognized in policy documents, resulting in wider participation in higher education. They see that with the massification of higher education, the students entering are more diverse and teaching and assessment methods must consider this. Not all students may have the same skills and competencies when entering higher education. They conclude that emphasis should be on the learning experience and personal gains over time.

New options for the design of learning

There are new options for the design of learning that can improve education.

New curriculum design

Graham (2018) concludes that five curricular themes will have to become increasingly prominent for future engineering education:

- Student choice and flexibility (educating students 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 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).

She sees that new world leaders in engineering education will likely be institutions that deliver an integrated and coherent student-centred curriculum to large student cohorts under constrained budgets. That curriculum should develop meta-cognitive

skills and the capacity for transfer and synthesis, as described by Van Damme (2022). Especially in the context of AI, advanced horizontal skills, such as high-level synthesis and decision-making in uncertain circumstances, become important. A massive curriculum redesign is needed to build those skills into university education. Lessons learned from introducing online learning in the past years should be considered. Such curricula can best be embedded within a well-designed modern educational ecosystem, as Den Brok (2018) described, using the dimensions of structure, connection, space and pedagogy.

The increasing role of ICT and digital resources in education

Van Damme (2022) sees that the pandemic has accelerated the development of distance education, online learning and hybrid approaches. He sees growing consensus that MOOCs can play a role for underserved populations and lifelong learners but not as an alternative to university education. In addition, the experience with online learning has not been overwhelmingly positive; research has indicated many negative outcomes. Students seem to value traditional formats such as in-person lectures and seminars. Wannemacher et al. (2022) discuss that the rapid conversion to digital teaching at the beginning of the pandemic shows that universities still have a long way to go. They explain this as the digital transformation affects the entire institution of higher education and its context, while many detailed questions and integrating approaches are still missing. van Puffelen et al. (2022) conclude that we should optimize blended education while remaining prepared for forced remote teaching. That requires a focus on well-being, a sense of connectedness between students and staff, and having online versions of courses available.

In addition, it is essential to recognize that students differ in preferences towards online and face-to-face Teaching and Learning Activities (TLA's). A carefully designed mix of TLA's is needed to activate most students.

It is not simply flipping one kind of TLA for another. In general, campus education remains essential and helps with a sense of connectedness and well-designed face-to-face TLA's, including a lecture, might help with that.

A new development is generating text using artificial intelligence. Baidoo-Anu and Owusu Ansah (2023) describe educational benefits of ChatGPT, like promoting personalized and interactive learning and generating prompts for formative assessment activities ongoing feedback to inform teaching and learning. They also highlight limitations like generating wrong information, biases in data training, which may augment existing biases and privacy issues. In addition, ChatGPT's high electricity consumption might be a concern (Ludvigsen 2023). Generally, a "we should not ignore but limit the use wisely" might be prudent at this stage.

Student-Centred Learning (SCL)

Graham (2018) and Green, Hertzman, and Banderlipe (2021) see an important role for SCL in reaching the required competencies of graduates. The question is how the student mindset needed for SCL can be achieved. Constantinou (2020) proposes an approach focusing on Goals, Organization, Actions, and Learning to achieve SCL. Forsythe and Jellicoe (2018) argue that the key to measuring learning gains might be to evaluate student progress by measuring self-reported positive changes in student behaviour rather than incremental changes in their grades. Martinie et al. (2022) focus on a potential problem for SCL: procrastination. They see procrastination as a self-regulation failure, especially in learning, such as effort regulation management. Mendo-Lázaro et al. (2022) found that using cooperative learning increases students' perceptions of autonomy and competence, and motivation for competence, intrinsic motivation, and learning control are boosted. Sun et al. (2022) found that the perceived value of knowing learning goals is a critical factor influencing online learning engagement. Learners who perceive that they know the learning goals are more likely to engage in online learning. Mishra and Braun (2021) advise project work, games, and simulations within the classroom to provide students with a broad range of skills and competencies and allow them to control their learning. Jivet et al. (2020) propose a tool that supports students in understanding their learning behaviour while starting to study. Students would get immediate feedback on their learning performance, be able to identify their strengths or weaknesses, gain insight into their learning strategies, build and refine their personal learner model, and develop self-regulated learning skills.

Boundary crossing (BC)

Michigan-state-University (2022) labels all broad/ horizontal skills needed for future workers as BC competencies. The many broad/horizontal skills seen as important in the articles referenced in this paper (see annex 1) would thus be BC competencies. Specific advice on how to train students to cross boundaries between disciplines, cultures and between university and society is given by Fortuin et al. (2020). They state that BC competence needs to be explicated, trained, practised and developed throughout a university study programme. That requires learning in situations that differ in the type of boundaries to cross, the number of boundaries, the 'difficulty' of (crossing) the boundaries, and focus on Identification, Coordination, Reflection, or Transformation.

Challenged based learning

Axelsson (2023) quotes Challenged based learning as a way to foster Innovative thinking abilities, improve interaction in the group and make students more involved.

As such, it could effectively train the horizontal part of the desired T-shape skills and stimulate BC.

Alternative credentials (AC)

Kato, Galán-Muros, and Weko (2020) noted that Higher Education Institutes, businesses and other institutions offer AC-like certificates, badges, and micro-credentials. The AC helps learners acquire skills and signal already-established competencies. They see that AC may have potential for some formal postsecondary education qualifications in selected sectors where AC are well known and recognised and are successful at attracting non-traditional learners, such as the IT sector. Likewise, micro-credentials that attempt to substitute substantial parts of postgraduate education programmes – such as MicroMasters credentials – may provide learners with skills and quality signals faster and cheaper than traditional programmes. This is limited by employers' unfamiliarity with these credentials, confusing signals caused by lack of standardisation, absence of validation procedures, and relative value of these credentials compared to other factors, such as professional experiences. McGreal and Olcott (2022) conclude that "micro-credentials are not a panacea for resolving institutional challenges, and they are unlikely to become a major revenue enhancement. They may provide strategic value in their integration with other major institutional initiatives".

Team role of teachers

The new education design causes teaching to become a team effort due to blended education and the new didactics, skills and tools needed for that (Wageningen University & Research 2022). It also makes it helpful to work and learn in teachers' network improvement community concentrating on Curriculum, Instruction, and Coherence, as described by Stone-Johnson and Hayes (2021). The participants grow in understanding of what quality curriculum and instruction coherence should be in a leadership preparation program.

Change within science and research

While changes within science and research can affect universities' research tasks in many ways, only one impact was found on education: the options created by the emergence of citizen science. Mitchell et al. (2017) combined citizen science with inquiry-based learning to offer first-year university students an authentic research experience.
A partnership with a citizen science program enabled biology students to contribute phenological data on plants and animals and conduct the first research on unvalidated species datasets from public and university participants. Students wrote scientific articles on their findings, peer-reviewed each other's work and published the best

articles online in a student journal. Surveys of more than 1500 students showed that their environmental engagement increased significantly after participating in data collection and data analysis. This seems a promising approach as it helps to reach multiple important parts of the T-shape skills, connects to a Citizen science community and increases the odds that graduates will remain connected to the university.

New societal roles for universities

Thirteen of the articles found discussed new societal roles for universities; the effect of those new roles on education can be expected but is not always clearly reported and might be indirect.

Development of societal roles of universities

Schofer, Ramirez, and Meyer (2021) point to the strong effects Higher Education has on this world. They found that higher-education enrolments are associated with key dimensions of rationalization, globalization, societal mobilization, and expansion of the service economy. They see that central features of modern society hinge on the distinctive form of higher education that has become institutionalized worldwide. Soysal and Baltaru (2021) showed that UK higher education embeds three institutional logics, knowledge production, economic value, and global actor-hood, which are linked with the broader transformations of the university toward proactive and societally engaged rational organization. Also, the global script of higher education might be pressured by the resurgence of anti-science and anti-education populism and nationalist politics. Ashwin (2022) wants to stop inequalities perpetuated by differences in higher education forms students gain access to. He sees the need to shift from focusing on the educational idea of 'the University' to the educational purposes of higher education systems.

Impact-focused education

According to Kamp (2019), Science & Technology universities must become more socially engaged and culturally open to remain relevant and take the lead. They have to become more active in the world. Universities should Intensify collaboration with industrial partners and promote impact-focused education through interdisciplinary student-centred projects with societal relevance. Graham (2022a) formulates this as a move towards socially relevant and outward-facing curricula. These curricula will emphasize student choice, multidisciplinary learning and societal impact and expose students to experiences outside the classroom, outside traditional engineering disciplines and across the world. Tassone et al. (2018) point to the urgent need to address the grand sustainability challenges of our time and conclude that it is important for Higher Education to focus on being relevant, responsive, and reflexive

(e.g., questioning the underlying normalized assumptions and values of one's endeavours) and to foster ethics of care (e.g., considering perspectives and needs of others and the ethical implications of endeavours). Sørensen et al. (2019) see an important role for a responsible university, which they define as an institution that carries out quality research and teaching, responds to the needs of society through basic tasks and aims at solving certain global problems while venerating the fundamental freedom of science. Compared to the present situation at many universities, this might mean an increase in societal tasks.

Balance between societal roles and interaction with employers and industry

The university plays an essential role in the education and social development of professionals, according to Sexson and Wilson (2021). They see that this role is vulnerable because state support is required to foster sustainability and resilience. Göransson, Chaminade, and Bayuo (2022) point to the financial autonomy of universities; pushing universities to be self-financed, gives a high risk that commercial innovations will be prioritised. Kusmin, Tammets, and Ley (2018) focus on how higher education institutions could engage employers and industry representatives into more systematic collaboration by creating environments for developing future workforce skills needed for Industry 4.0. They propose that a dynamic work-integrated curriculum might allow learners to quickly contextualize study content and develop field-specific and self-regulated learning competences through work integrated learning study process. Géring et al. (2018) found two issues on which students and staff differed in opinion for their university:

1. Openness to market forces and demands, as it might enhance the employability of students (student vision), it also undermines the idea of the university as a relatively independent and autonomous entity (teachers' vision).

2. The composition of the student body. While teachers, considering a dwindling number of young students, opt for lower barriers to HE and a more diverse student body, students emphasise the need to select the most motivated, committed and dedicated students who create a favourable learning environment for each other.

Continuous/lifetime education: upskilling and relearning

Van Damme (2022) states that we need flexible lifelong learning because the half-life time of skills is shortening. That requires a shorter initial education with more flexible combinations of part-time study and work later in life. Universities have no monopoly on lifelong learning but can play a role with innovative approaches.
They will retain an important role in research-based education in a 'network education arrangement': educational programmes offered in cooperation, for instance, joint degrees and executive master programmes with industry and European

University alliances. Kamp (2020) sees options for lifelong partnerships with students: “For companies, lifelong learning programmes need to provide state-of-the-art knowledge and perspectives to their employees. The need for workforce agility in the gig economy increases the demand for continuous development. Continuous learners have different demands and expectations than regular students. New-age learners are more "consumerised", want a quick return on investment and full control of their learning path. They want learning that is learner-centred, affordable, technology-enabled, and preferably creative and innovative. They want packages delivered by the best lecturers and available from a pool of modules. They re-bundle them into personalized curricula and stack credits gained from on-campus courses and lab work with new credentials such as open badges, nano degrees or micro-credentials. Universities that aim to make continuous education part of their mainstream activities must co-design curricula and courses in partnership with employers and students”.

The influence of national higher education policy

Vabø and Langfeldt (2020) conclude that state ownership may be important in maintaining their university and its technology teams' high social and scientific standing – both as a protector against cyclical fluctuations in the student market and through specific national initiatives and measures to strengthen these subjects. Another example of state influence are three goals for higher education set by the Dutch government (OCW, 2022):

1. Strengthening a healthy and strong foundation for the system of higher education and science, with peace and space for students, researchers and lecturers and profiling of institutions.

2. On that basis, giving space to diverse talent. As a result, the country can further distinguish itself internationally on many themes.

3. Increasing the social impact of higher education and research and public recognition of this.

Such a policy aligns with global trends, but national policies change every few years, driving uncertainty in Higher Education (Pelletier et al. 2022). This makes it difficult to anticipate the impact of policy in the long run.

4. Discussion

For four change drivers, the search resulted in a number of papers within the 11 to 22 range. Two drivers returned few papers: “Change within science and research”: only one paper and “The population of learners and changes therein”: three papers. For both these drivers, relevant search terms were used. These were (shown between brackets): [chang* science] respectively [“future graduates”], [“types of students”] and [student characterisation]. However, the terms might have been too restrictive. For instance, the driver “changes in population of learners” had the first two search terms between quotes, requiring finding the exact given word sequence. In future research, other or less restrictive search terms could be used to determine if that was the case. Certainly, “The population of learners and changes therein” seems worth more focus in future research, with the challenge of discovering the difference in local and global shifts. Apart from that, the chosen drivers fit the articles' content well.

In general, it is difficult to relate the number of papers found to the importance of a topic. Most papers are at least partly empirically based, but as we look for vision of the future, personal opinion might play a role in the entire process, from selecting a research topic to formulating conclusions. That might cause important topics to be chosen less; for instance, the tendency of university staff to focus on science itself (Graham 2022b) might lower focus on the effect that changing science could have on education. So, the results cannot lead to the selection of a few most important trends, but they should be taken into account together to provide a broad view of important developments for the future. Most papers focus on general advice and are not very specific on how to implement solutions for the challenges. This is an area in which more research is needed.

5. Conclusions

The articles found point to many topics with common ideas: change is needed due to strong developments, as shown below.

Future graduates of universities will face problems that change more quickly and are complex. This is caused by rising population and urbanisation, societal trends, changes due to geopolitical shifts, and strong challenges to reaching sustainable development goals.

The articles found showed consensus that future graduates need T-shaped skills to tackle the uncertain future and the high speed at which new complex problems develop. The type of these challenges gives extra importance to two horizontal competencies of that "T": sustainability, competence, and the ability to successfully participate in solving wicked problems. The discussion above gives suggestions on how to train the horizontal "T" part of competencies; embedding students within complex real-world challenges often features in them.

Universities should anticipate changes in the population of learners. Curricula must be suitable for diversity in entry-level learning skills and international backgrounds and provide students with a sense of belonging.

The new options for the design of learning are needed to reach the new learning goals and allow new roles and position of the university. The discussion section gives ideas for new curriculum design, increasing role of ICT and digital resources, student-centred Learning, boundary crossing, alternative credentials and the team role of teachers. Implementing these options, focusing on T-shaped skills, including sustainability and wicked problems, requires an integrated approach. Well-designed educational ecosystems can offer an essential part of that approach, as described by Den Brok (2018). Such an ecosystem has emphasis on the system as a whole and how the different parts interact with each other.

Citizen science can be combined with university education, creating a rich learning environment that helps foster multiple T-shaped skills (Mitchell et al. 2017).

Universities should more actively take their share of the market for lifetime education: upskilling & relearning to retain their central educational role in society.

Universities should increase their societal impact to remain relevant and to introduce more options for real-life (wicked) problem-oriented education. Education has to be partly impact-focused. Independence and societal roles should be well balanced with interaction with employers and industry. It becomes even more critical that national policy stimulate universities to have societal roles independent from finance. That stimulation can also help universities anticipate new challenges, but universities should do that without policy stimulation as well.

As indicated in the introduction, the advice searched for is relevant for future graduates working on societal or corporate challenges using Beta and Gamma sciences. But except for parts of the discussed “competencies of future graduates”, the trends might also be relevant for Alpha Sciences. Generally, most Universities can use the (sub) drivers and the advice to check and formulate their policies.

The extensive list of horizontal competences of the “T” found in this study (annex 1) raises the question which of them should be introduced into curricula. And a related question is presented by the wicked problems of our VUCA world and the recent acceleration of world developments. Should universities shift focus to educating resilience for quick changes, sense of belonging, well-being and life skills? The traditional role of universities might not allow a complete move from savoir-faire (teaching how to make things) to savoir-vivre (how to live one’s life with a different employment pattern), as suggested by Moscardini et al. (2022). Still, a small move in that direction is an option.

In most articles, the advice for change does not include estimates on how far universities' more traditional science and knowledge roles will be affected. There is consensus that the vertical and horizontal parts of education towards “T” shaped skills could at least be partly integrated within complex real-world challenges, but detailed curriculum advice on the balance between fundamental science education versus integrated skills education is not given. More research on this is needed, which might have to be study program title-specific.

Universities might already anticipate some of the trends. However, all the trends together suggest the need for change at the three educational levels: system, curricula, and courses. The literature scan yielded no articles on the combined effect of trends and the combined changes needed at the three educational levels. This area requires more research: a more specific literature scan and more research leading to articles on this topic. A first idea can be obtained by using the system-level change in terms of educational ecosystems, as discussed by Den Brok (2018). He advises on education design for Structure, Connections, Culture, Pedagogy and Spaces. When there is a clear definition of the required T-shape skills of graduates available, the curriculum and courses can be drafted by integrating them into that educational ecosystem while using ideas found in the results section: Developments in the population of learners and in: New options for the design of learning. Additional considerations with details in the result section are the effect of changes within science and research and new societal roles for universities.

6. Disclosure statement

No potential conflict of interest was reported by the authors.

7. Acknowledgement

The authors thank their colleagues of the four Dutch Technical Universities for their input within 4TU.CEE meetings. That input gave inspiration for this research and paper. They also thank Maiko Cheng and Helen Hartmann for their assistance with the report layout.

8. Funding

This work was funded by the 4TU.Centre for Engineering Education, which supports innovation and research in technical education in the Netherlands.

9. References

4TU.CEE. "4TU.CEE Publications." https://www.4tu.nl/cee/Publications/.

Acosta Castellanos, Pedro Mauricio, and Araceli Queiruga-Dios. 2022. "From environmental education to education for sustainable development in higher education: a systematic review." *International Journal of Sustainability in Higher Education* 23 (3):622-644. https://doi.org/10.1108/IJSHE-04-2021-0167.

Ashwin, P. 2022. "The educational purposes of higher education: changing discussions of the societal outcomes of educating students." *Higher Education* 84 (6):1227-1244. https://doi.org/https://doi.org/10.1007/s10734-022-00930-9.

Axelsson, J. 2023. "Challenge-based learning and impact." In, 17. The European Consortium Of Innovative Universities.

Baidoo-Anu, David, and Leticia Owusu Ansah. 2023. "Education in the era of generative artificial intelligence (AI): Understanding the potential benefits of ChatGPT in promoting teaching and learning." *Available at SSRN 4337484*.

Bezanilla, M. J., H. Galindo-Domínguez, and M. Poblete. 2021. "Importance of teaching critical thinking in higher education and existing difficulties according to teacher's views." *Multidisciplinary Journal of Educational Research* 11 (1):20-48. https://doi.org/https://doi.org/10.447/remie.2021.6159.

Constantinou, C. S. 2020. "A reflexive GOAL framework for achieving student-centered learning in european higher education: From class learning to community engagement." *Societies* 10 (4). https://doi.org/10.3390/soc10040075.

Den Brok, Perry. 2018. "Cultivating the growth of life-science graduates: on the role of educational ecosystems." In.

Donoso-González, M., I. Pedraza-Navarro, and L. Palferro-Fernández. 2022. "Analysis of Entrepreneurial Education—Study of the Configuration of the Entrepreneurial Identity through the Acquisition of Crucial Transversal Competences for Future University Students." *Education Sciences* 12 (5). https://doi.org/10.3390/educsci12050310.

Forsythe, A., and M. Jellicoe. 2018. "Predicting gainful learning in higher education; a goal-orientation approach." *Higher Education Pedagogies* 3 (1):82-96. https://doi.org/10.1080/23752696.2018.1435298.

Fortuin, KPJ, NC Post Uiterweer, JTM Gulikers, C Oonk, and CWS Tho. 2020. Training students to cross boundaries between disciplines, cultures and between

university and society: developing a boundary crossing learning trajectory. Paper presented at the SEFI Annual Conference 2020.

Fox, Mo. 2023. "Simple - Complex - Wicked - Problems - SummaryChart." https://mofox.com/wp-content/uploads/2018/10/Simple-Complex-Wicked-Problems-SummaryChart.pdf.

Gan, T. Y., Z. Beevi, J. Low, P. J. Lee, and D. A. Hall. 2022. "Developing Future-Ready University Graduates: Nurturing Wellbeing and Life Skills as Well as Academic Talent." *Frontiers in Psychology* 13. https://doi.org/10.3389/fpsyg.2022.827517.

Gáspár, J., É Hideg, and A. Köves. 2021. "Future in the Present: Participatory Futures Research Methods in Economic Higher Education – The Development of Future Competencies." *Journal of Futures Studies* 26 (2). https://doi.org/10.6531/JFS.202112_26(2).0001.

Geertshuis, S., R. Wass, and Q. Liu. 2022. "Equipping graduates with future-ready capabilities: an application of learning theories to higher education." *Teaching in Higher Education*. https://doi.org/10.1080/13562517.2022.2137399.

Géring, Z., G. Király, S. Csillag, G. Kováts, A. Köves, and T. Gáspár. 2018. "Vision(s) of the university. Applying participatory backcasting to study the future of higher education." *Journal of Futures Studies* 22 (4):61-82. https://doi.org/10.6531/JFS.201806.22(4).0005.

Göransson, B., C. Chaminade, and B. B. Bayuo. 2022. "Transforming universities to address grand societal challenges: A case study of organisational and institutional change at Lund University." *International Journal of Intellectual Property Management* 12 (1):13-41. https://doi.org/10.1504/IJIPM.2022.120990.

Graham, Ruth. 2018. "The global state of the art in engineering education." In. Cambridge, MA 02139 USA: Massachusetts Institute of Technology (MIT).

———. 2022a. "Crisis and catalyst: The impact of COVID-19 on global practice in engineering education." In, 89. Massachusetts Institute of Technology (MIT).

———. 2022b. "Teaching Cultures Survey 2022 findings." In.

Green, M. J., E. J. Hertzman, and M. R. Banderlipe. 2021. "Resilience and growth: A University's response for future-proofing graduates and careers." In *Education in the Asia-Pacific Region*, 89-104. Springer.

Grosemans, I., L. Coertjens, and E. Kyndt. 2020. "Work-related learning in the transition from higher education to work: The role of the development of self-

efficacy and achievement goals." *British Journal of Educational Psychology* 90 (1):19-42. https://doi.org/10.1111/bjep.12258.

Hüsing, Tobias, Carola Schulz, Werner B. Korte, and Alexander Cuartas-Acosta. 2020. "Skills for Industry; Fostering New Services and Jobs Creation." In *EUROPEAN COMMISSION*, edited by EUROPEAN COMMISSION. EUROPEAN COMMISSION.

Islam, M. S., and K. Stamp. 2020. "A reflection on future directions: Global international and intercultural competencies in higher education." *Research in Comparative and International Education* 15 (1):69-75. https://doi.org/10.1177/1745499920901951.

Jivet, I., M. Scheffel, M. Schmitz, S. Robbers, M. Specht, and H. Drachsler. 2020. "From students with love: An empirical study on learner goals, self-regulated learning and sense-making of learning analytics in higher education." *Internet and Higher Education* 47. https://doi.org/10.1016/j.iheduc.2020.100758.

Kamp, Aldert. 2016. *Engineering Education in a Rapidly Changing World; Rethinking the Vision for Higher Engineering Education*. Second Revised Edition ed. Delft: Delft University of Technology, Faculty of Aerospace Engineering.

———. 2019. "Science & technology education for 21st century Europe; CESAER discussion paper 18th december 2019." In.: CESAER discussion paper 18th december 2019.

———. 2020. *Navigating the Landscape of Higher Engineering Education. Coping with decades of accelerating change ahead.* First ed. Delft.

Kato, Shizuka, Victoria Galán-Muros, and Thomas Weko. 2020. "The Emergence of Alternative Credentials. OECD Education Working Paper No. 216." In *OECD Education Working Papers*. OECD.

Kleimola, R., and I. Leppisaari. 2022. "Learning analytics to develop future competences in higher education: a case study." *International Journal of Educational Technology in Higher Education* 19 (1). https://doi.org/10.1186/s41239-022-00318-w.

Kusmin, K. L., K. Tammets, and T. Ley. 2018. "University-industry Interoperability Framework for Developing the Future Competences of Industry 4.0." *Interaction Design and Architecture(s)* (38):28-45. https://doi.org/10.55612/S-5002-038-002.

Lemmens, A.M.C. 2015. *TU/e Bachelor College : well-founded innovation in education*. Eindhoven, the Netherlands: Eindhoven University of Technology.

Ludvigsen, Kasper Groes Albin. 2023. "ChatGPT's electricity consumption, pt. II." (12 june 2023).

Martinie, M. A., A. Potocki, L. Broc, and P. Larigauderie. 2022. "Predictors of procrastination in first-year university students: role of achievement goals and learning strategies." *Social Psychology of Education*. https://doi.org/10.1007/s11218-022-09743-1.

McGreal, Rory, and Don Olcott. 2022. "A strategic reset: micro-credentials for higher education leaders." *Smart Learning Environments* 9 (1):9. https://doi.org/10.1186/s40561-022-00190-1.

McPhillips, M., and M. Licznerska. 2021. "Open innovation competence for a future-proof workforce: a comparative study from four European universities." *Journal of Theoretical and Applied Electronic Commerce Research* 16 (6):2442-2457. https://doi.org/10.3390/jtaer16060134.

Mendo-Lázaro, S., B. León-del-Barco, M. I. Polo-del-Río, and V. M. López-Ramos. 2022. "The Impact of Cooperative Learning on University Students' Academic Goals." *Frontiers in Psychology* 12. https://doi.org/10.3389/fpsyg.2021.787210.

Michigan-state-University. 2022. "What is the "T"?" In.

Mishra, S., and E. Braun. 2021. "The changing role of higher education: From social/societal aspect to employability gains." In *International Perspectives on Higher Education Research*, 87-99. Emerald Group Holdings Ltd.

Mitchell, Nicola, Maggie Triska, Andrea Liberatore, Linden Ashcroft, Richard Weatherill, and Nancy Longnecker. 2017. "Benefits and challenges of incorporating citizen science into university education." *PloS one* 12 (11):e0186285. https://doi.org/10.1371/journal.pone.0186285.

Moscardini, A. O., R. Strachan, and T. Vlasova. 2022. "The role of universities in modern society." *Studies in Higher Education* 47 (4):812-830. https://doi.org/https://doi.org/10.1080/03075079.2020.1807493.

Mueller, Milton L., and Karim Farhat. 2022. "Regulation of platform market access by the United States and China: Neo-mercantilism in digital services." *Policy & Internet* 14 (2):348-367. https://doi.org/https://doi.org/10.1002/poi3.305.

NAE. 2017. "NAE Grand challenges for engineering." In.

Nölting, B., H. Molitor, J. Reimann, J. H. Skroblin, and N. Dembski. 2020. "Transfer for sustainable development at higher education institutions-untapped potential for

education for sustainable development and for societal transformation." *Sustainability (Switzerland)* 12 (7). https://doi.org/10.3390/su12072925.

Pedler, Megan Louise, Royce Willis, and Johanna Elizabeth Nieuwoudt. 2022. "A sense of belonging at university: student retention, motivation and enjoyment." *Journal of Further and Higher Education* 46 (3):397-408. https://doi.org/https://doi.org/10.1080/0309877X.2021.1955844.

Pelletier, Kathe, Mark McCormack, Jamie Reeves, Jenay Robert, Nichole Arbino, Camille Dickson-Deane, Carlos Guevara, Lisa Koster, Melchor Sanchez-Mendiola, and Lee Skallerup Bessette. 2022. "2022 EDUCAUSE Horizon Report Teaching and Learning Edition." In, 58. EDUCAUSE.

Rittel, Horst WJ, and Melvin M Webber. 1973. "Dilemmas in a general theory of planning." *Policy sciences* 4 (2):155-169.

Riuttanen, L., T. Ruuskanen, M. Äijälä, and A. Lauri. 2021. "Society needs experts with climate change competencies–what is the role of higher education in atmospheric and Earth system sciences?" *Tellus, Series B: Chemical and Physical Meteorology* 73 (1):1-14. https://doi.org/https://doi.org/10.1080/16000889.2021.1917862.

Schiefloe, Per Morten. 2021. "The Corona crisis: a wicked problem." *Scandinavian Journal of Public Health* 49 (1):5-8. https://doi.org/https://doi.org/10.1177/140349482097076.

Schofer, E., F. O. Ramirez, and J. W. Meyer. 2021. "The Societal Consequences of Higher Education." *Sociology of Education* 94 (1):1-19. https://doi.org/10.1177/0038040720942912.

Sexson, W. R., and M. J. Wilson. 2021. "The university's fragile role in fostering societal resilience by facilitating the development of community-engaged professionalism." *Law Teacher* 55 (1):88-100. https://doi.org/https://doi.org/10.1080/03069400.2021.1872882.

Sørensen, Mads P, Lars Geschwind, Jouni Kekäle, and Rómulo Pinheiro. 2019. *The responsible university: Exploring the Nordic context and beyond*: Springer Nature.

Soysal, Y. N., and R. D. Baltaru. 2021. "University as the producer of knowledge, and economic and societal value: the 20th and twenty-first century transformations of the UK higher education system." *European Journal of Higher Education* 11 (3):312-328. https://doi.org/https://doi.org/10.1080/21568235.2021.1944250.

Stephens, J. C., E. Palchak, and B. Reese. 2017. "Divestment and Investment: Strategic Financial Decisions in Higher Education to Promote Societal Change Toward Sustainability." In *World Sustainability Series*, 305-315. Springer.

Stone-Johnson, C., and S. Hayes. 2021. "Using Improvement Science to (Re)Design Leadership Preparation: Exploring Curriculum Change Across Five University Programs." *Journal of Research on Leadership Education* 16 (4):339-359. https://doi.org/https://doi.org/10.1177/1942775120933935.

Sun, W., J. C. Hong, Y. Dong, Y. Huang, and Q. Fu. 2022. "Self-directed Learning Predicts Online Learning Engagement in Higher Education Mediated by Perceived Value of Knowing Learning Goals." *Asia-Pacific Education Researcher*. https://doi.org/https://doi.org/10.1007/s40299-022-00653-6.

Tassone, Valentina C, Catherine O'Mahony, Emma McKenna, Hansje J Eppink, and Arjen EJ Wals. 2018. "(Re-) designing higher education curricula in times of systemic dysfunction: a responsible research and innovation perspective." *Higher Education* 76 (2):337-352.

United Nations. 2015. "Transforming our world: The 2030 agenda for sustainable development." In *Resolution adopted by the General Assembly 25 September 2015*. New York, USA: United Nations.

United Nations, Department of Economic and Social Affairs, Population Division. 2019. "World Urbanization Prospects: The 2018 Revision." In, 103. New York: United Nations.

United Nations Department of Economic Social Affairs, Population Division. 2022. "World Population Prospects 2022: Summary of Results." In.: United Nations New York, NY, USA.

Van Damme, Dirk 2022. "Higher education in transition or transformation?" In *104th Dies Natalis Wageningen University & Research; Metamorphoses. Shaping tomorrow's university education.* Wageningen:www.wur.nl/en/show/lecture-dirk-van-damme-dies-natalis-9-march-2022.htm.

van Puffelen, E.A.M. , T.M. Stevens, S.K. Banihashem, H.J.A. Biemans, O. Noroozi, N.S.M. Raeven, and P.J. den Brok. 2022. "Covid-19 forced remote teaching and university education after it." In *the 18th International CDIO Conference*, 12. Reykjavík: Reykjavík University / CDIO.

Van Puffelen, Emiel, and Marijke van Oppen. 2020. "Supporting cross-cultural university education." In *16th International CDIO Conference*, 112-121. Hosted on-line by Chalmers University of Technology, Gothenburg, Sweden, 8-10 June 2020.

Wageningen University & Research. 2022. "Finding answers together; Extension & Update Strategic Plan 2019 | 2024." In, 16. Wageningen: Wageningen University & Research.

Waller, Robert E, Pamela A Lemoine, Evan G Mense, Christopher J Garretson, and Michael D Richardson. 2019. "Global higher education in a VUCA world: Concerns and projections." *Journal of Education and Development* 3 (2):73.

Wals, Arjen EJ. 2015. "Beyond unreasonable doubt." *Education and learning for socio-ecological sustainability in the Anthropocene*.

Wannemacher, K., M. Lübcke, F. Seyfeli-Özhizalan, and V. Graceva. 2022. "Reimagining the Future of Higher Education Teaching: A Contrastive Evaluation of General Trend Reports and Pandemic-Specific Surveys on Higher Education." In *Lecture Notes in Networks and Systems*, 7-30. Springer Science and Business Media Deutschland.

Žalėnienė, Inga, and Paulo Pereira. 2021. "Higher Education For Sustainability: A Global Perspective." *Geography and Sustainability* 2 (2):99-106. https://doi.org/https://doi.org/10.1016/j.geosus.2021.05.001.

10. Appendix 1

Overview of horizontal parts of T-shaped competencies/skills for future graduates found.

Article	Horizontal Competencies/skills for Future Graduates
Acosta Castellanos and Queiruga-Dios (2022)	Need to shift from environmental focus to focus on sustainable development.
Bezanilla, Galindo-Domínguez, and Poblete (2021)	Critical thinking
Donoso-González, Pedraza-Navarro, and Palferro-Fernández (2022)	Entrepreneurial identity: leadership, creativity, autonomy, initiative, entrepreneurial knowledge and skills
Gan et al. (2022)	Well-being and life skills
Gáspár, Hideg, and Köves (2021)	Foresight competence: forward-looking thinking and back-casting; more responsible and future-conscious economic actors
Geertshuis, Wass, and Liu (2022)	Generic capabilities for students for an uncertain future
Green, Hertzman, and Banderlipe (2021)	Independent thinking and global citizens who will make a difference also in future
Grosemans, Coertjens, and Kyndt (2020)	Self-efficacy and achievement goal orientation
Hüsing et al. (2020)	T-shaped and ready for new high-tech jobs and advanced service
Islam and Stamp (2020)	Global, International, and Intercultural (GII) competencies
Kamp (2020)	Technical and data literacy, agile and resilient, critical and holistic thinkers, can work outside their comfort zones, interdisciplinary global team worker, ethical leader
Kleimola and Leppisaari (2022)	Reflective competence, self-awareness and self-management, learning literacy, personal agency and self-efficacy, digital competence
Lemmens (2015)	Disciplinary basis and broad skills: collaboration, communication, information and ICT literacy, social and cross-cultural skills, creativity, innovation, critical thinking, decision making, flexible problem solving, adaptability, openness, learning to learn and entrepreneurial skills
McPhillips and Licznerska (2021)	Creativity, Entrepreneurship, and Cooperation as parts of Open Innovation Competence
Michigan-state-University (2022)	T-shape, Boundary Crossing Competencies (Teamwork, communication, perspective, networks, critical thinking, global understanding, project management, etc)
Van Puffelen and van Oppen (2020)	A global mindset and the ability to effectively operate in a multicultural environment
Wals (2015)	Can handle wicked problems and boundary crossing. Sustainability competence examples: Sustainability literacy, Systems thinking, Adopting an integral view, Learning to know, Questioning hegemony and routines, Analysing normativity, Disruptiveness, transgression, Learning to critique, leadership and entrepreneurship, Unlocking creativity, utilizing diversity, Appreciating chaos & complexity, Adaptation, resilience Empowerment and collective change, Learning to make change, Connecting with people, places and other species, Passion, values and meaning-making, Moral positioning, considering ethics, boundaries and limits, Learning to be, learning to care