Researching Engineering Education in a Rapidly Changing World: looking back, moving forward

Personalised Engineering Education in Southern Africa Conference (PEESA III)

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PERI

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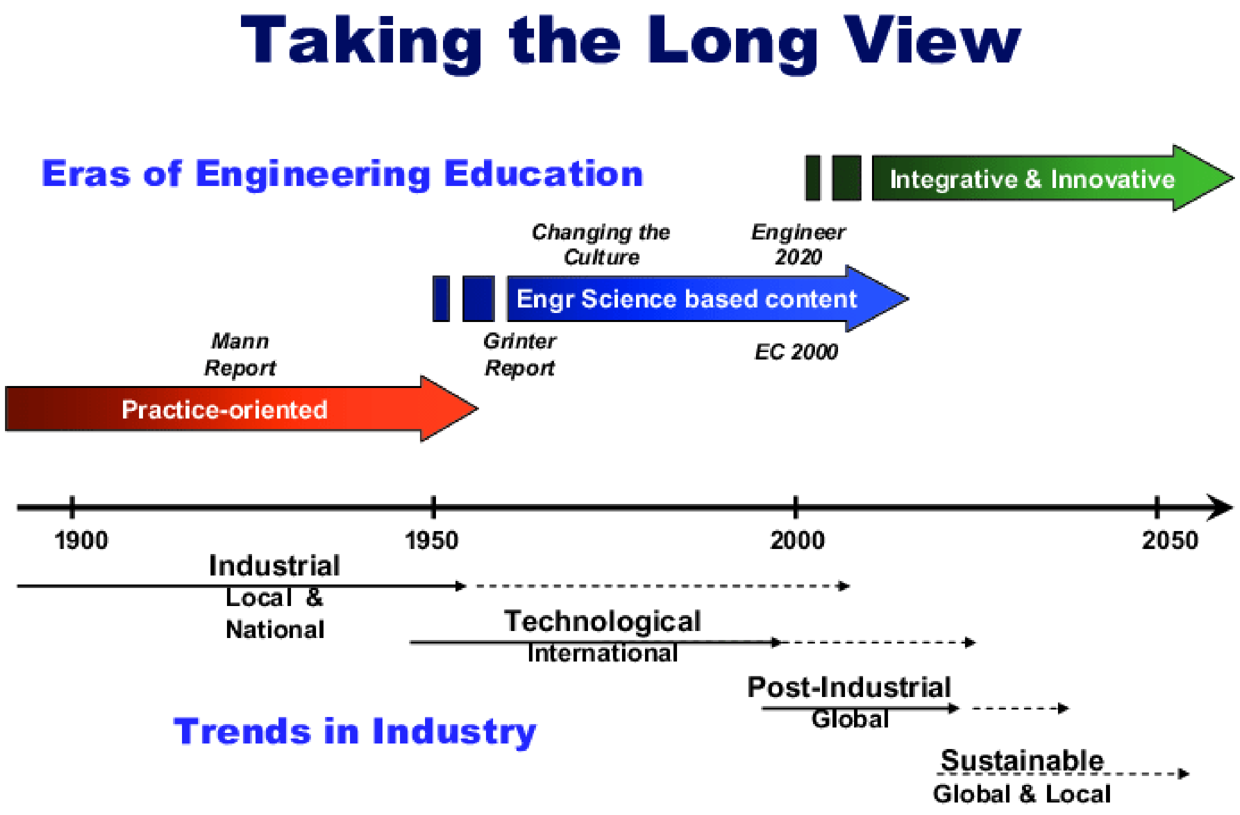
Overview

- ❑Background;
- ❑Five trends:
- - Employability;
- - Industry 4.0;
- - SDGs;
- - Identity;
- - AI, CPSs in education.
- ❑Everything's connected…



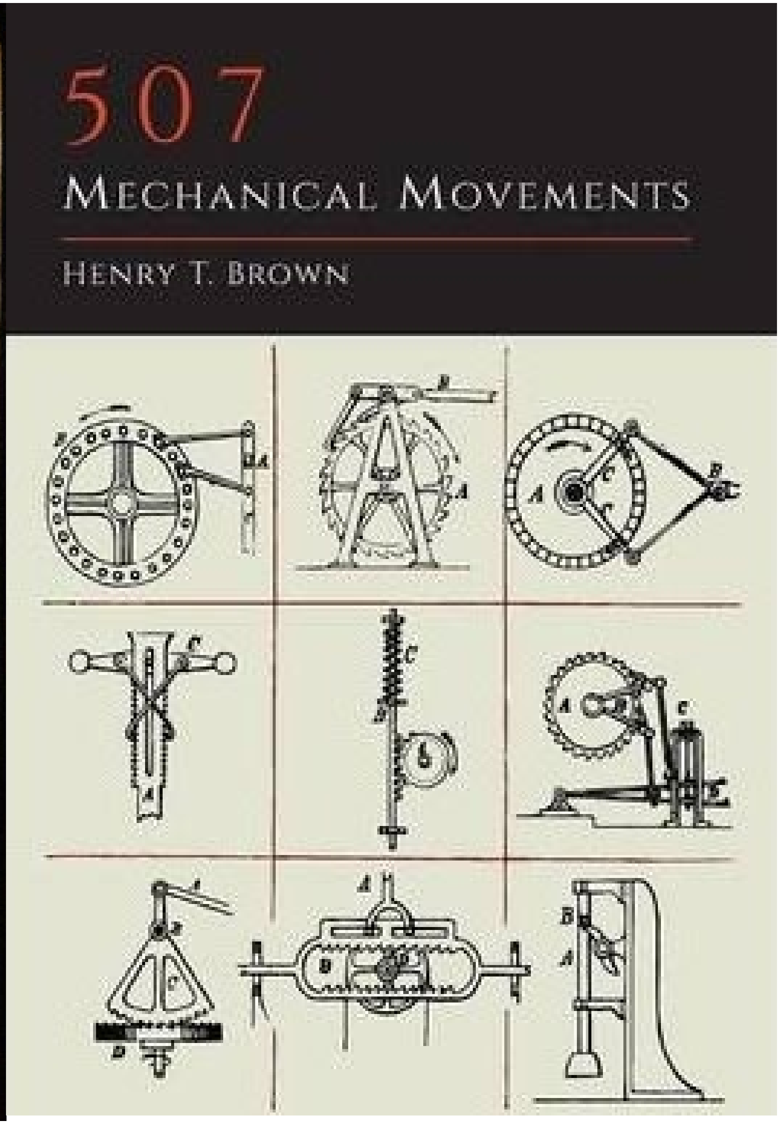
Putting this address together…

Data sources for this presentation:

1. Survey of most read and most cited journal articles in JEE, EJEE and IEEE Transactions on Education.
2. Reports (e.g., UNESCO 2021);
3. Interviews with employers (both local and international) for a current project on professional skills for Industry 4.0.

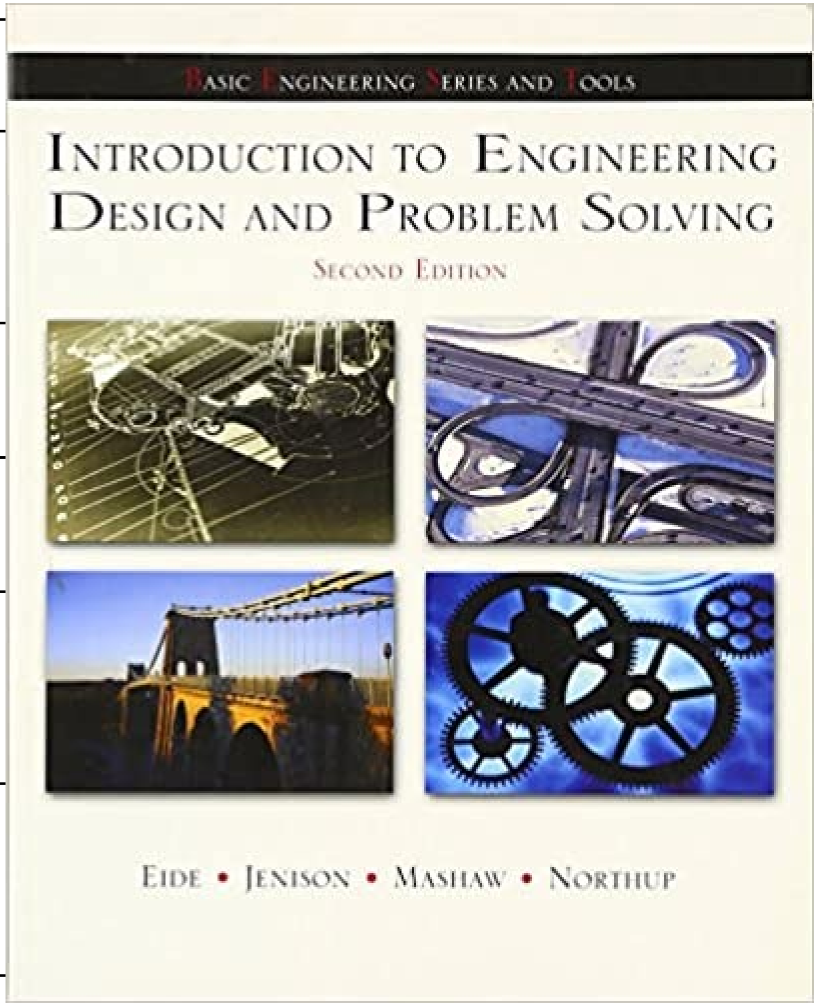
Engineering education: past

	Back in the day….
❶	Shift from engineering as practice to engineering as science.
❷	Programme accreditation by a professional council;
❸	A new emphasis on engineering design;
❹	Application of social and cognitive research to engineering education;
❺	New technologies introduced in pracs and labs. 'Lecture-demo' as signature pedagogy



Engineering education: past, present

	Back in the day....	30 years ago....
1	Shift from engineering as practice to engineering as science.	Early concerns about losing touch with practice and issues of employability of graduates.
2	Programme accreditation by a professional council;	OBE, GAs, quality issues and increasing control by councils.
3	A new emphasis on engineering design;	Problem-based learning and project-based learning.
4	Application of social and cognitive research to engineering education;	General recognition of the importance of active and engaged learning.
5	New technologies introduced in pracs and labs. 'Lecture-demo' as signature pedagogy	Integrating ICTs in education – specialist teaching technologies (e.g., MatLab).



Engineering education: past, present, futures

	Back in the day….	30 years ago….	Future trends
❶	Shift from engineering as practice to engineering as science.	Early concerns about losing touch with practice and issues of employability of graduates.	Employability concerns are increasing – particularly wrt engineers' contributions.
❷	Programme accreditation by a professional council;	OBE, GAs, quality issues and increasing control by councils.	Technical and professional skills for Industry 4.0.
❸	A new emphasis on engineering design;	Problem-based learning and project-based learning.	The SDGs, grand challenges – and interdisciplinarity and creativity.
❹	Application of social and cognitive research to engineering education;	General recognition of the importance of active and engaged learning.	Engineering identity: issues in social inclusion, race, gender, ability and in issues of wellbeing.
❺	New technologies introduced in pracs and labs. 'Lecture-demo' as signature pedagogy	Integrating ICTs in education – specialist teaching technologies (e.g., MatLab).	Blended/online learning and assessment, simulation, educational AI and Cyber Physical Systems.

Engineering education: past, present, futures

	Back in the day….	20 years ago….	Now – and in future
❶	Practice-ba… as scien…	…focus	Employability – curriculum transitions (student → engineer).
❷	Progra… profess…		Technical and professional skills for Industry 4.0.
❸	A new … engine…		Interdisciplinarity, millennium goals and grand challenges.
❹	Apply s… science… engine…		Engineering identity (issues in social inclusion, race and gender).
❺	New te… in prac… demo' a…		Blended, online learning and assessment, simulation, educational cyber physical systems

UVUCA

Unequal/unjust

Volatile

Uncertain

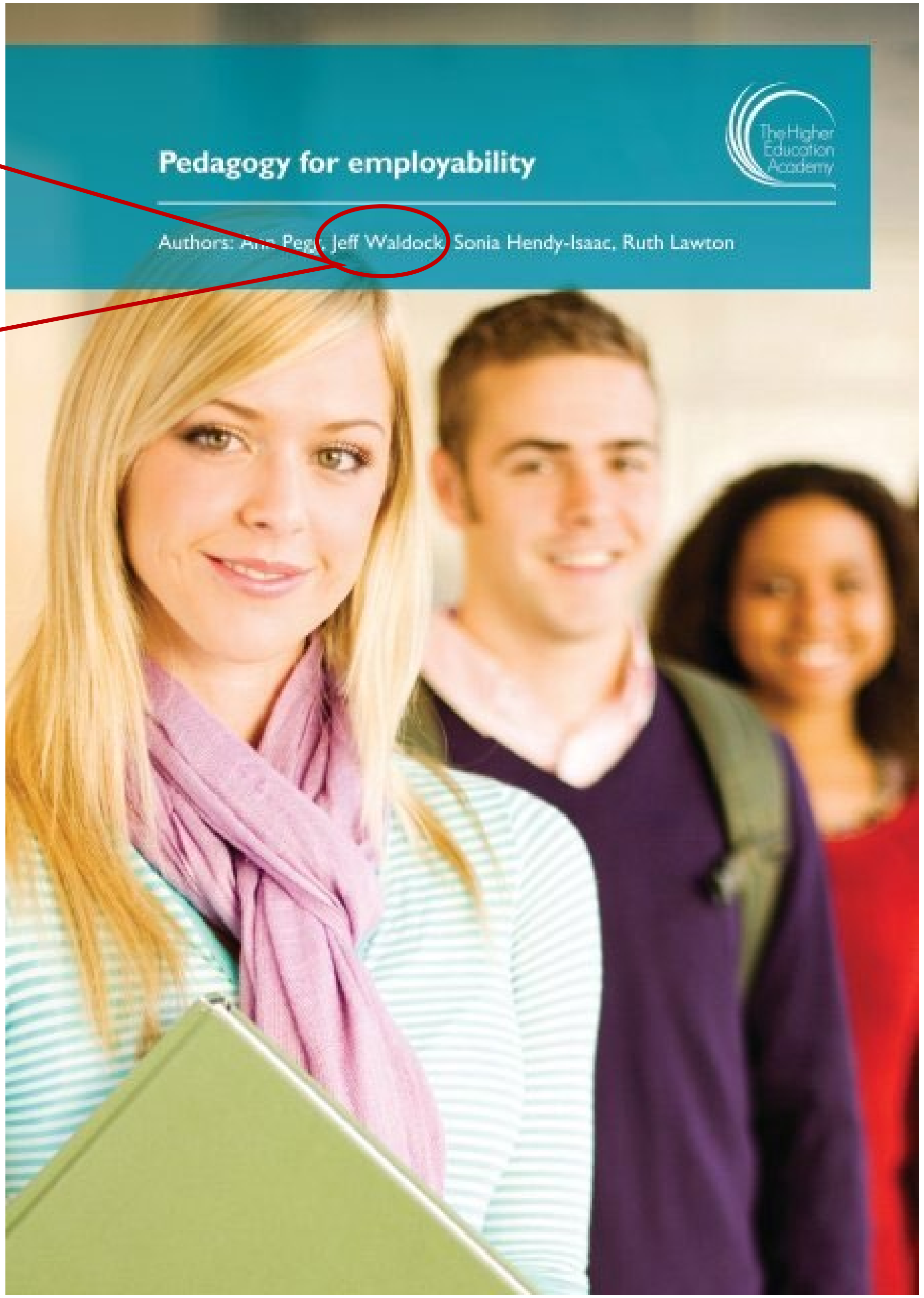
Complex

Ambiguous

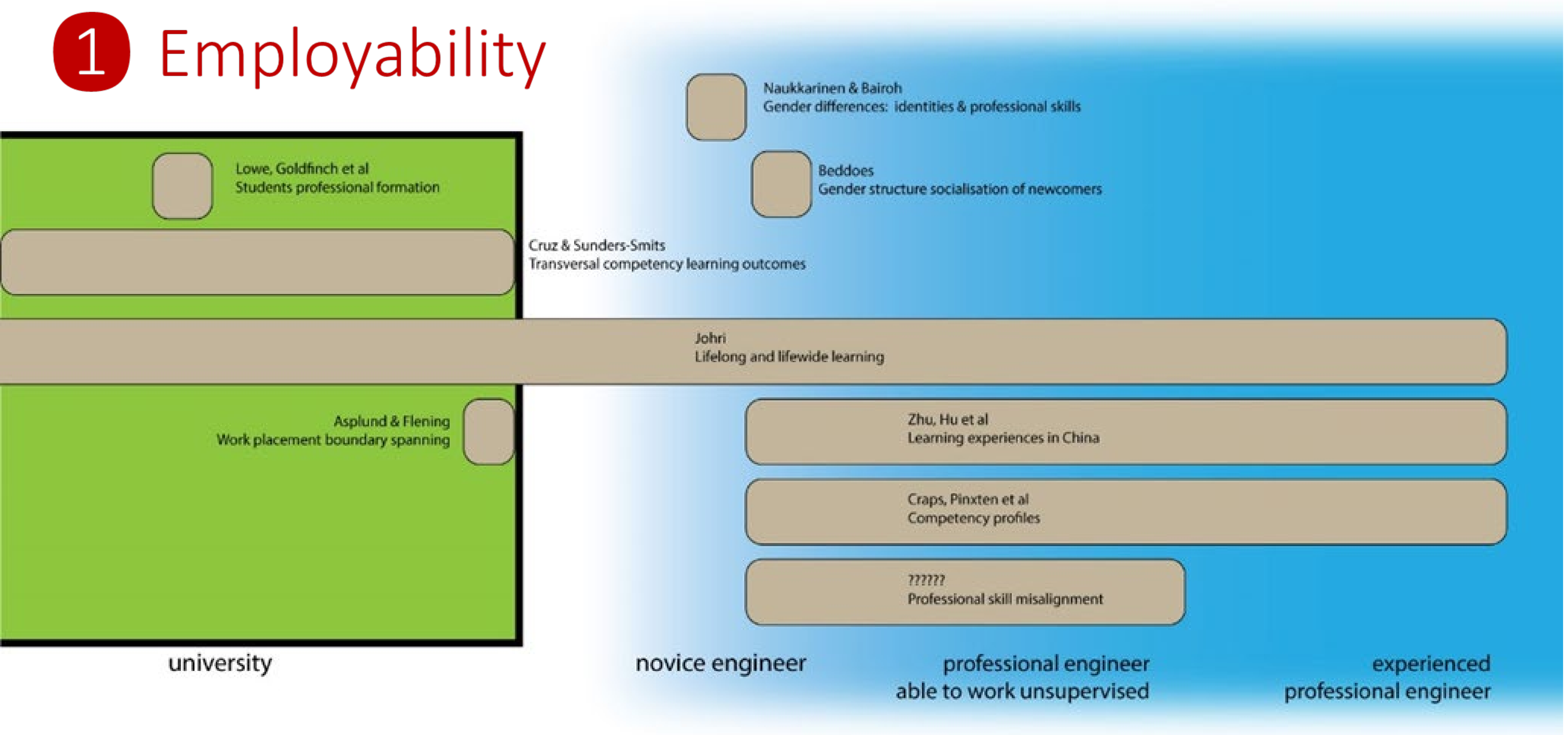
1 Employability

Mismatch between "…what engineering science professors want to teach students to do, so that they can become young scientists and PhD students, and the needs of government and society, which is to create engineers to contribute to economic development and growth." (Graham, 2018)

Our SHU partner on the EEESCEP project, produced very useful 'pedagogy of employability' materials for the SA context, together with iengineering academics from CPUT, SU and MUT and industry partners…



1 Employability



Map by Prof James Trevelyan for the special issue of EJEE on early career engineers…

1 Employability: employer interview

The interdisciplinary team

Installing wind turbines is the end point of a very long process [and] expertise and experience at all the stages of the process are needed – procurement engineers and design engineers and project managers and site engineers who can properly plan and manage installations [and] maintenance engineers, renewable engineering portfolio analysts to complete the cycle. We even hire ornithologists because bird observations are very important in wind farm installations (Employer 1)

What do you bring to the company?

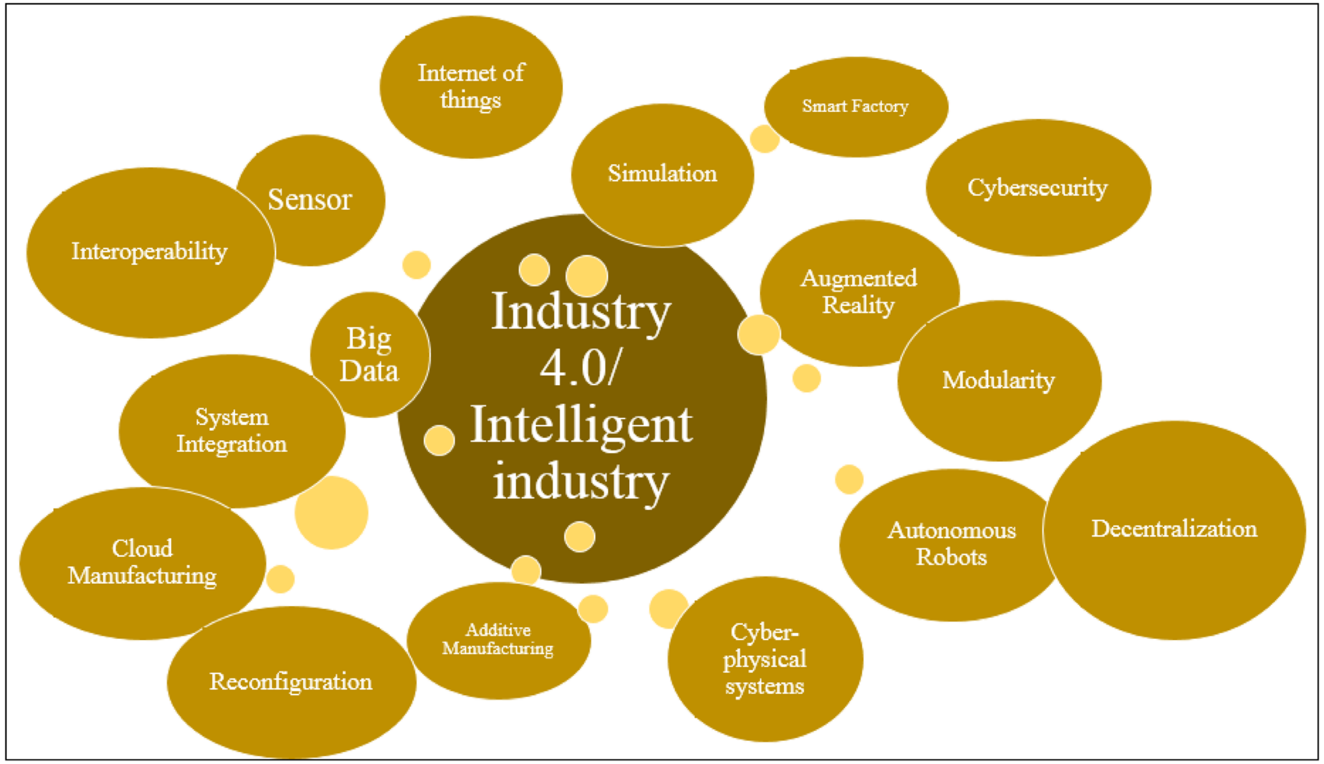
Employers value skills and job seekers must be able to explain the skills they possess and how these relate to the job that they are applying for. Simple I know, but very few applicants can tell us, for example, that they applied big data in case study, or that they developed an algorithm in their research class (Employer 2).

❷ Industry 4.0

1) Digitization of work and workplaces;
2) Industrie 4.0 (Hannover Fair, 2012);
3) Fourth Industrial Revolution (Schwab, 2016 at the World Economic Forum's Annual Meeting);
4) Employability for 4IR…

2 Industry 4.0 – the ecosystem

Universities should work more closely with tech companies. We are trying to build this industry and they are producing the professionals for this industry, so obviously we must work together – we are all part of the tech ecosystem. You cannot be in a university and ignore what is happening in the big tech companies, if you do you will soon become irrelevant (Employer 3).



2 Industry 4.0: employer interviews

Technical ⟷ **Other (interpersonal, leadership, etc.)**

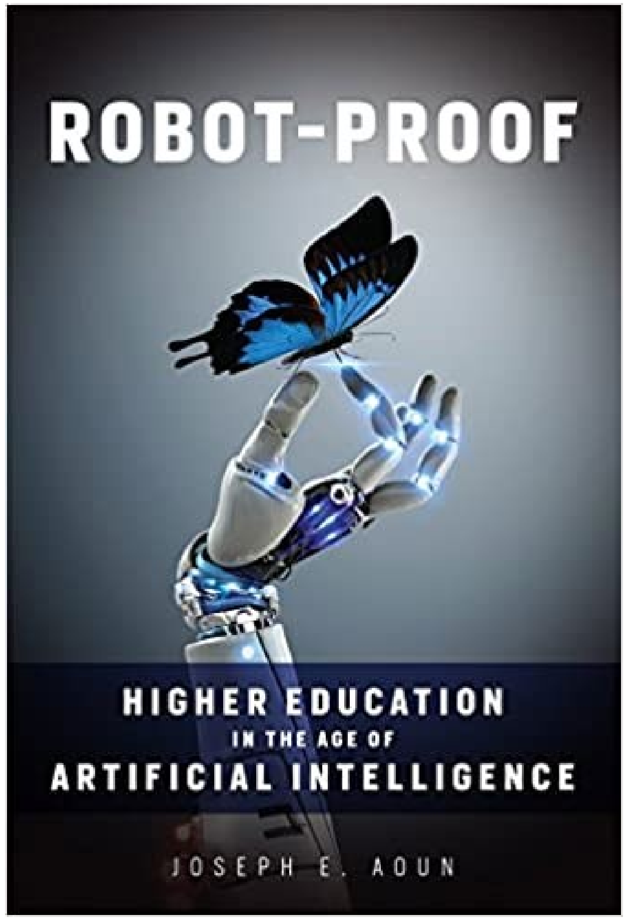
When it comes to digital skills I think there are three levels – we can say basic, intermediate and advanced so when we employ an IT professional or a computer engineer such a person should have very high level tech skills but everyone we employ needs to have the skills for working in an AI-enabled environment. I'd say that what we are looking for now is really more of the advanced tech skills…We will train them on the platforms and technologies that we have developed in-house but they need to be highly competent in automated production technologies (Employer 4)

When I think about the interviews I've conducted over the past couple of years I can identify the person who will be able to contribute to our company's vision. I will usually ask a question about a new technology – something like cloud computing or IoT – and wait for the response. The person whose eyes light up and can't stop speaking about it, well that's my next hire (Employer 5).

2 Industry 4.0 – professional skills

- More than digital skills are required in Industry 4.0.
- Professional skills
- analytical thinking,
- systems thinking;
- communication skills,
- Teamwork,
- leadership skills' (Aoun, 2017).

I can find engineers, I can find software guys, and I can find good data scientists … It is harder to find someone who can draw all the threads together to oversee the team of specialists' (Aoun, 2017: 36).



③ SDGs and the Grand Challenges

1) Linking graduate attributes to the sustainable development goals;
2) Inter-professional education;
3) Greater interdisciplinary;
4) Transdisciplinarity in education;
5) Ethics education;
6) Creativity.

3 Radical inequality (SDG #1)

SDG 1

1 NO POVERTY

How engineering can make it happen

Engineering drives economic growth and alleviates poverty through basic infrastructure such as roads, railways and telecommunications. However, much engineering work remains to be done to develop technologies that improve access to basic services such as clean water and sanitation, reliable energy and clean cooking fuels. Large populations in low-income countries are demanding access to the latest technologies for communication, education and health. Frugal innovation enables the development of affordable and reliable technologies that are accessible to all.

- Engineering education for social development (e.g. water, sanitation, energy, fuels);
- "Frugal innovation" (UNESCO, 2021).

3 Climate Change: employer interview

When I interview someone I usually tell them about a problem that I'm dealing with in a design and we'll talk about how the person would handle that. After a bit of this conversation – where I'm trying to imagine the person as a part of my team – well having this conversation tells me if the person is a good fit for the practice [and] if they are going to take up the challenge of architecture in harmony with nature (Employer 6).

Stefano Boeri, Bosco Verticale, Milan

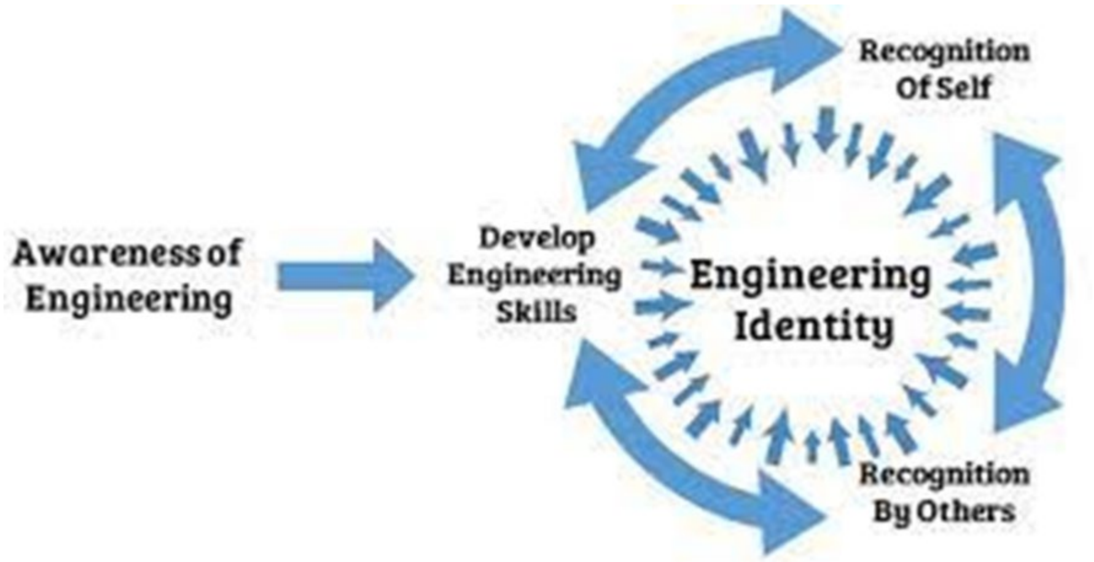
Inclusion of creative studies in engineering curricula (Bruhl & Klosky 2020)

3 SDGs start at home…

"Campuses that address the climate challenge by reducing their own global warming emissions and by integrating sustainability into their curriculum will better serve their students and meet their social mandate to help create a thriving, ethical, civil society" (American College and University Presidents' Climate Commitment, 2012).

4 Engineering identity

- Technical problem-solving;
- Creativity and innovation;
- Communication, ethics, social impact, and lifelong learning, (Morelock, 2017);
- Sense of belonging (Schell & Huges, 2017).



Schell & Huges, 2017

4 Engineering identity

1) Unpacking engineering identities;
2) Social inclusion;
3) Student experiences (gender, race, disability);
4) Epistemic justice and decolonization;
5) Mental health for engineering students and engineers

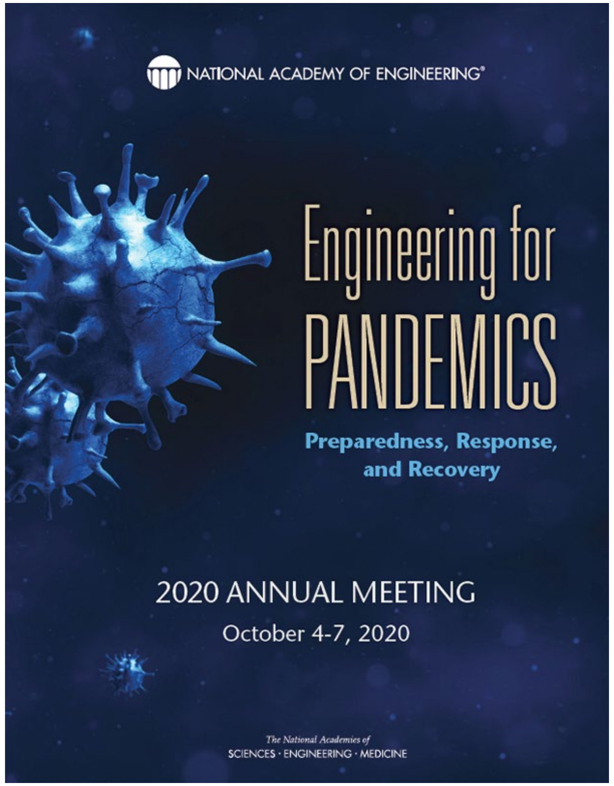
TABLE 2: Synthesis of results: The impact of laboratory spaces and practices on emergent engineering identities.

Dimensions of identity	Activities in engineering laboratories need to...	Laboratory affordances	Signature laboratory pedagogies that support identity formation	References
Temporal	... affirm students' prior identities in an engineering environment	Orientation	'Tiered mentoring' orientation in which senior, demographically diverse, students orient first-year students	2, 12
	... cultivate a sense of belonging in engineering	Inclusion	Collaboration between students at all levels on research and design	26
	... promote early identification with engineering	Induction	Encourage role play in the laboratory (e.g. user, assembler and analyst); avoid stereotypes in role allocation	17, 31
	... shape students' aspirations towards a future engineering identity	Aspiration	Simulated workplace projects and the inclusion of workplace collaborators and/or assessors	34, 37
Spatial	... facilitate students' diverse learning styles and abilities	Engagement	Laboratories can support diverse learning styles and disabilities	2, 9, 14
	... engage students in engineering problem-solving and design	Modelling	Spaces that promote interactions with 'fellow students, teachers and industry' are key to identity formation	5, 6, 7, 10
	... introduce students to modelling techniques	Simulation	Blended laboratories should support investigation into real-world phenomena through simulation models	11, 13, 36
	... extend to 'real-world' social contexts beyond the laboratory	Field testing	The 'ecological, social and technical' become interconnected in field testing	40, 42, 43
Material	... introduce students to basic engineering tools	Familiarisation	'Person-to-artefact cognitive partnering' in which engineering tools represent familiar and trusted processes over time	27, 41, 49
	... introduce students to specialised engineering tools	Specialisation	Mastery of specialised tools (and their socio-material affordances) is key to a specialised engineering identity	10, 45, 47
	... encourage students to apply tools to social/ environmental problems	Contribution	Interdisciplinary projects/ teamwork (e.g. with medical students) support emerging engineering identities	50
	... support innovative problem-solving and design	Innovation	Generic laboratories, beyond the basic 'cognition, psychomotor and affective domains' enable creativity	46
Performative	... introduce students to engineering problem-solving and research processes and methods	Experimenting/ problem-solving	Early undergraduate research experiences support an emerging engineering identity	28, 33
	... enable students to become designers	Design	Design challenges enable emerging engineering identities without sacrificing existing identities	18, 35
	... enable others to affirm students' engineering identity/ performance	Demonstration	Structures and practices to support multiple/critical engineering agencies	4, 8, 15, 19, 51
	... help students to assess their engineering identity/ performance	Assessment	In-class assessment and conventional report-based assessment for optimal laboratory learning	44, 48
Discursive	... encourage intraprofessional communication	Narrating	Telling engineering 'disaster stories' (and other engineering narratives) is inclusive and affirming	39
	... encourage interprofessional communication	Reporting	Technical communication is best learned in an engineering laboratory	52, 53
	... provide opportunities for extraprofessional communication	Translating	Being able to communicate engineering to non-engineers (and influence of public perceptions)	55
	... encourage collegial, inclusive communication practices	Presenting	Competence in presenting and arguing on a scientific basis	54

Pedagogies to enhance identity formation (Winberg & Winberg, 2021).

❺ The pivot online

- The pandemic has accelerated shift towards online learning;
- An explosion of articles on blended and online modalities, virtual laboratories, simulations, etc.



AI in Engineering and Computer Science Education in Preparation for the 4th Industrial Revolution: A South African Perspective

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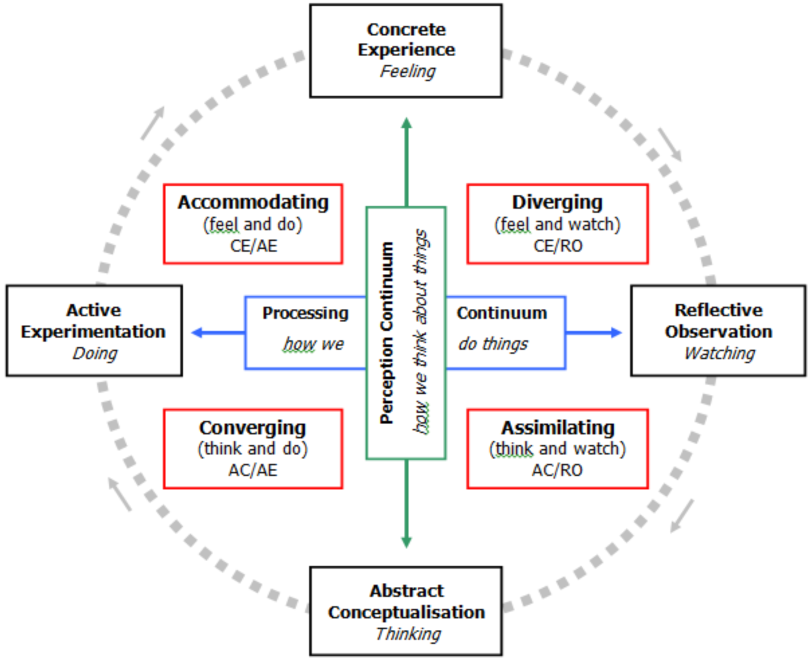
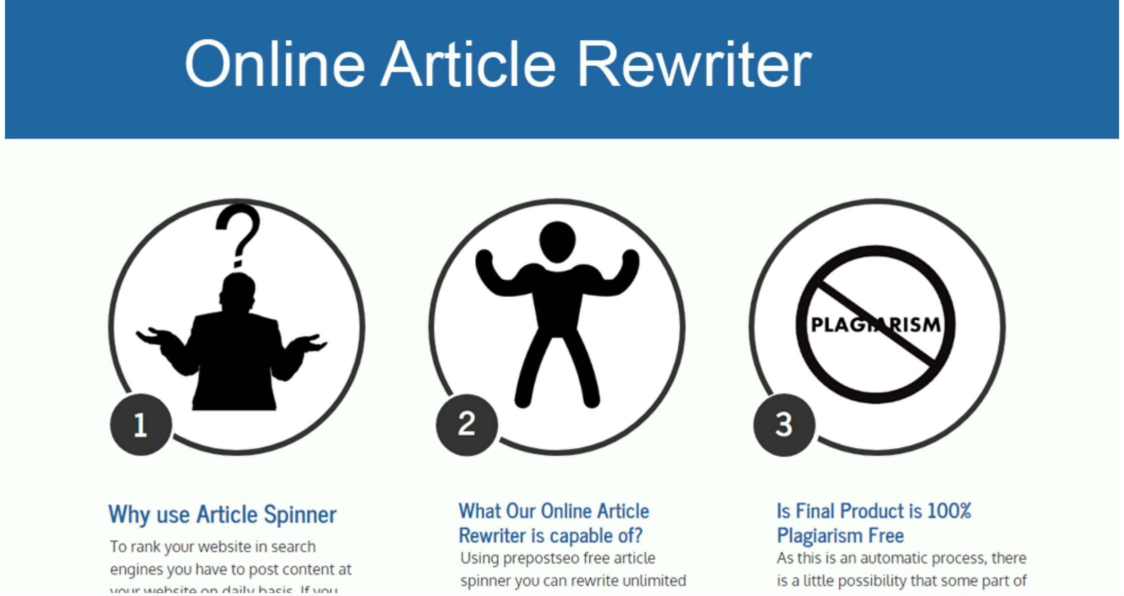


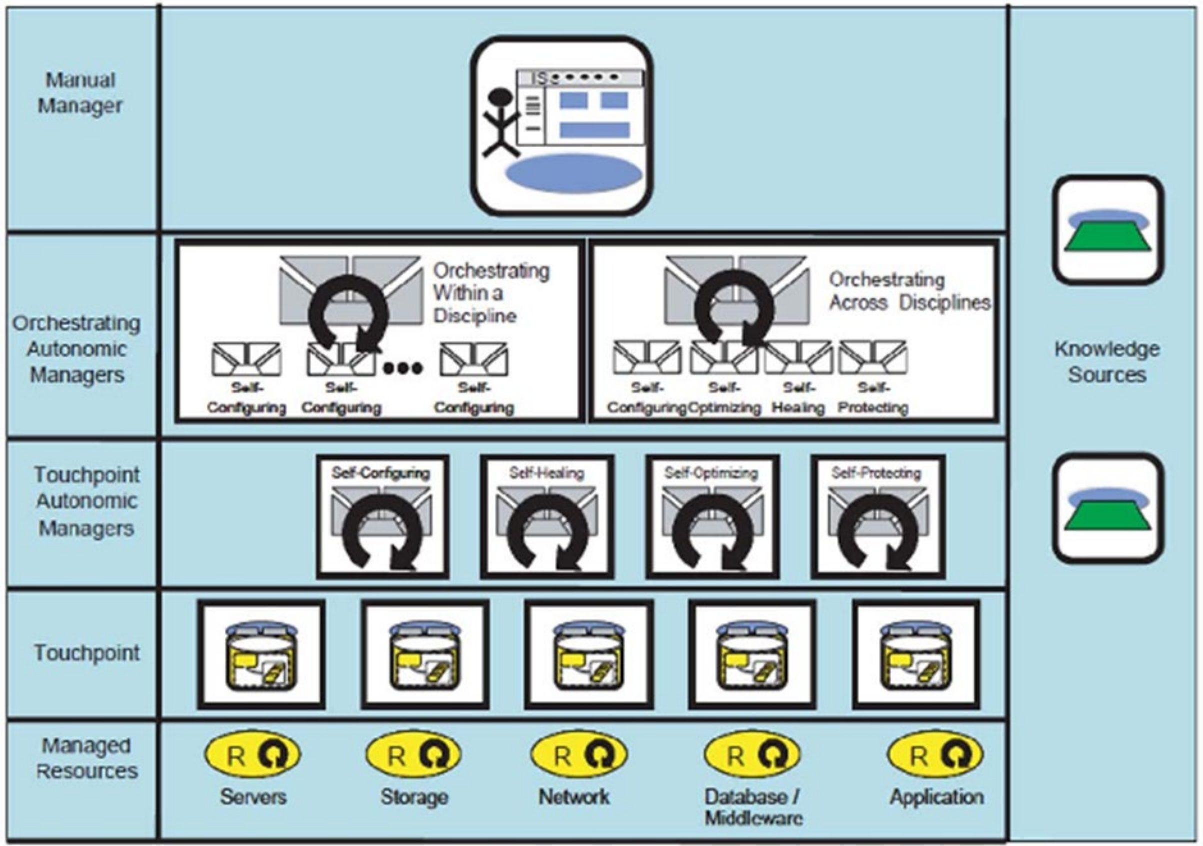
5 "Educational" AI/CPSs

Some of the online technologies are useful – and linked to Industry 4.0 – but others??!!

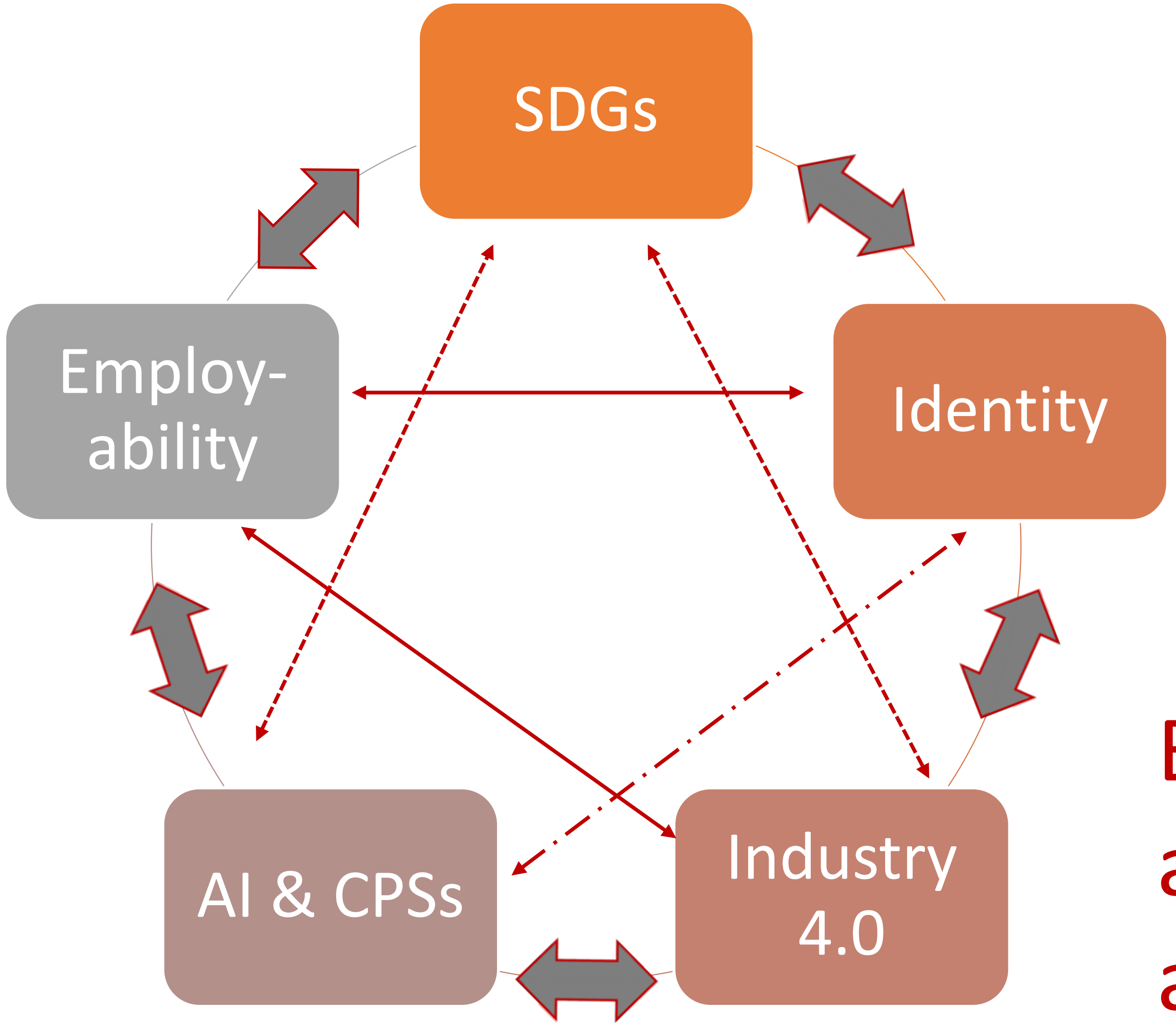
QuillBot

Writing Made Painless





Everything's connected…



But not always aligned…

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