How to educate the systems architecting work force of the future? What we can learn from today's education

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Abstract

The systems that we engineer have evolved from closed mostly hardware systems 50 years ago to socio-technical cyber physical systems of systems anno 2025. Behind any physical system,we see many related virtual systems, such as digital threads, shadows, and twins, and a variety of simulation models for many purposes. How can we educate the (systems architecting) workforce for the future systems?

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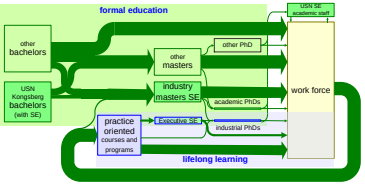

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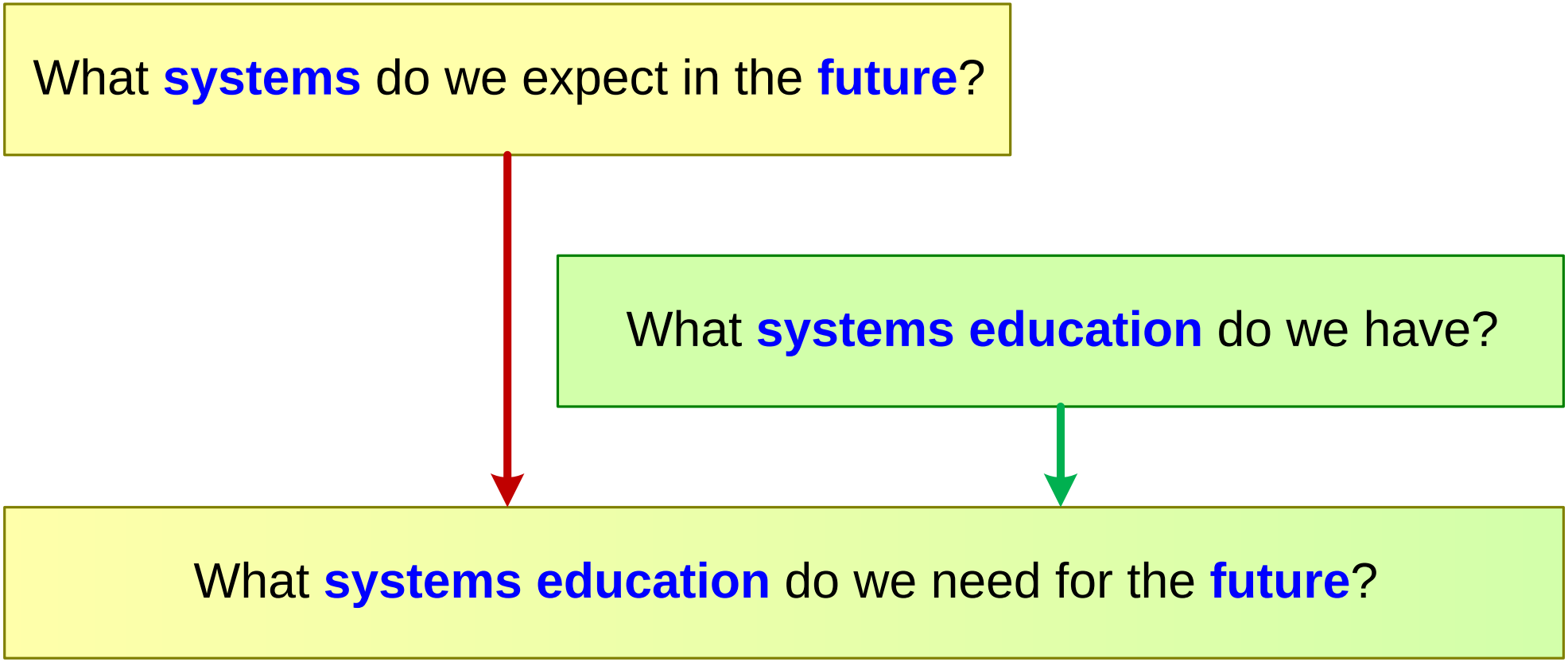

What do you Perceive as the Main Trend in Systems?

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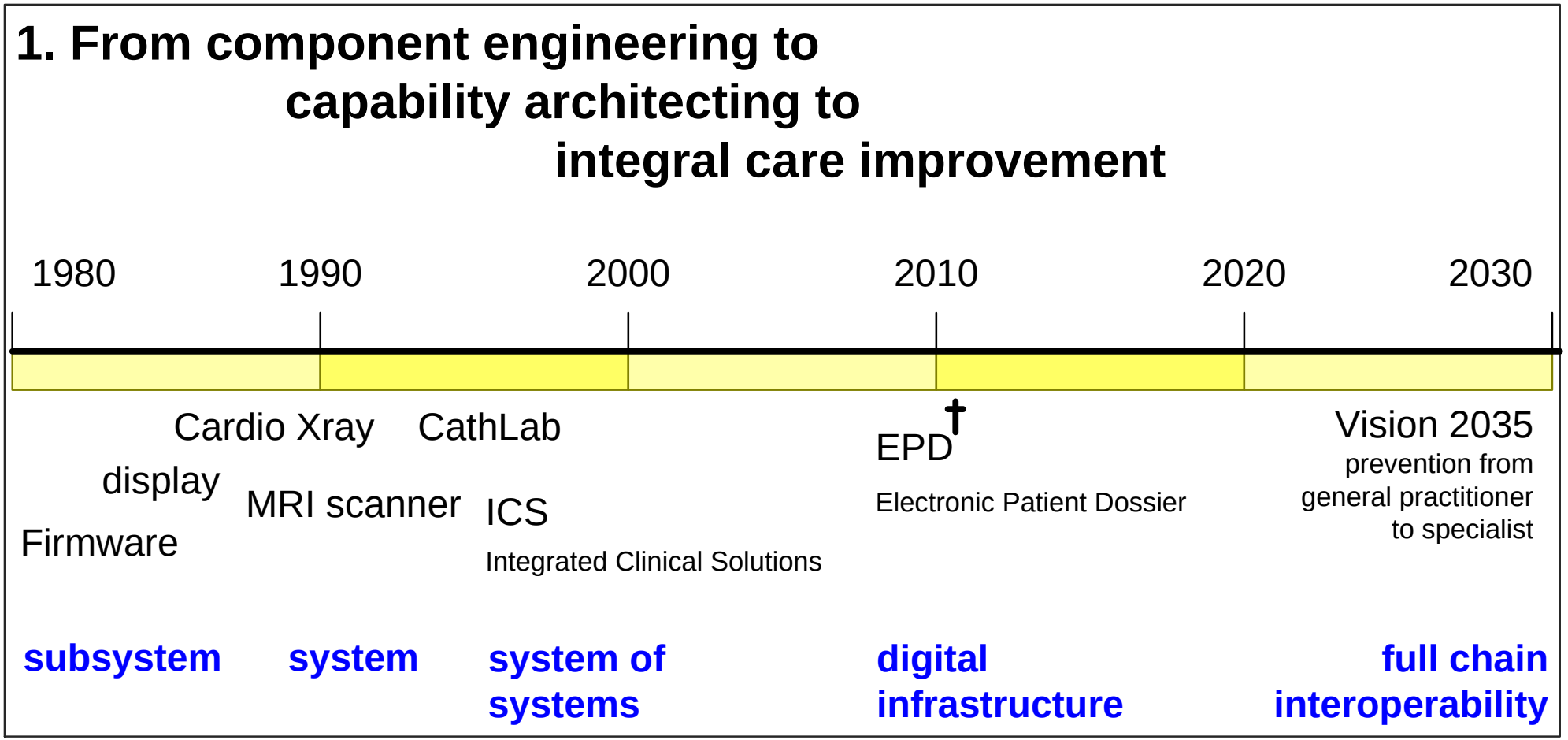
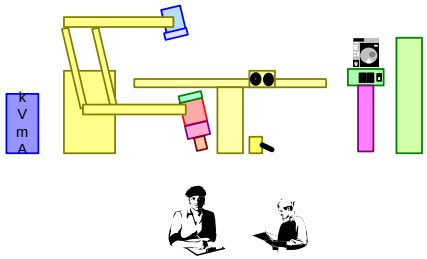
System Trends

- anno 2025, systems are **socio-technical cyber-physical systems-of-systems**
- these systems operate in **extensive ecosystems**
- **humans and organizations** cause **complexity**
- climate emergency: **sustainability** is an additional container of qualities
- political emergency: **security** is critical
- **digital technologies** enable capabilities across constituent systems
- biological, clinical, pharmaceutical, material science, **and many more technologies** change rapidly

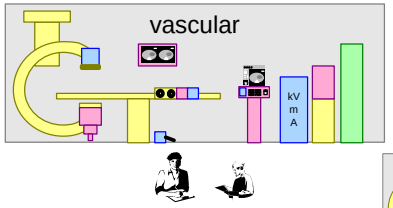
Example Scope Increase in Healthcare



Example Scope Increase in Cardio

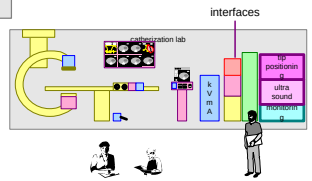


subsystems



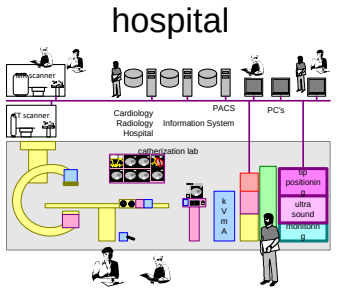
system

catharization lab

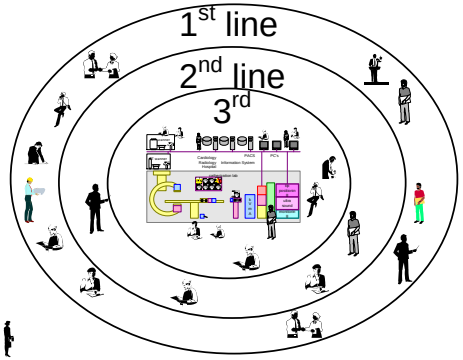


system of systems

hospital

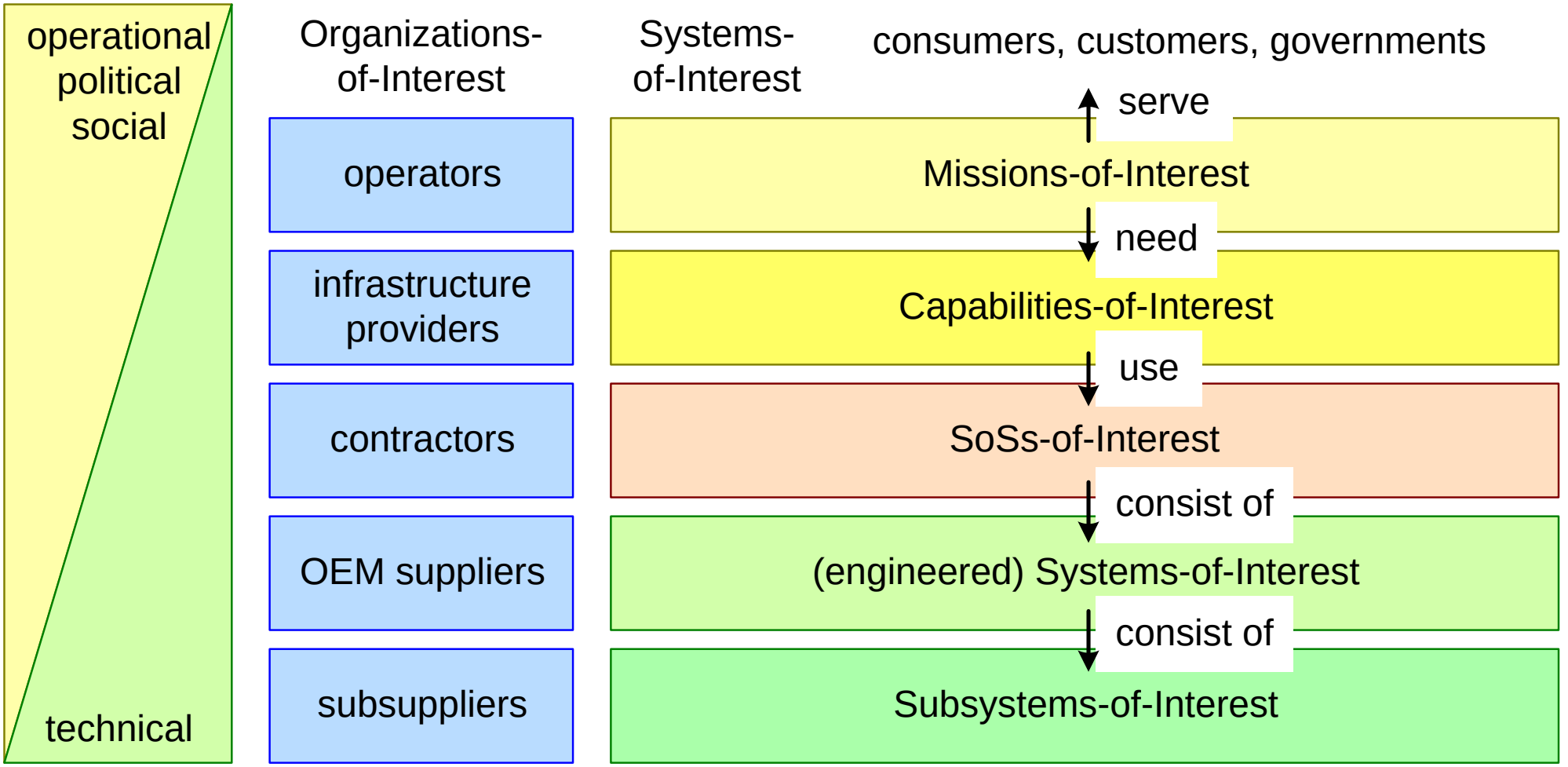


digital infrastructure



full chain interoperability

We Need Many Types of Architects



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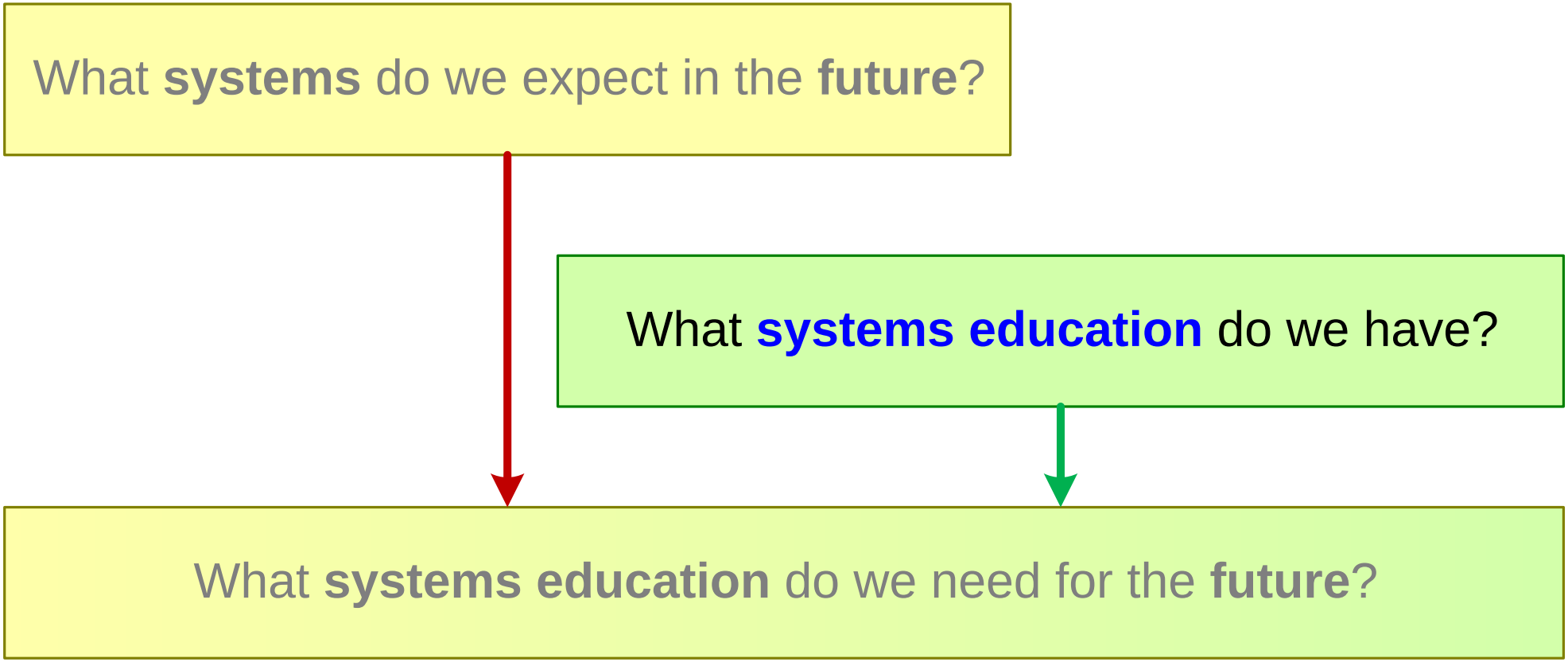
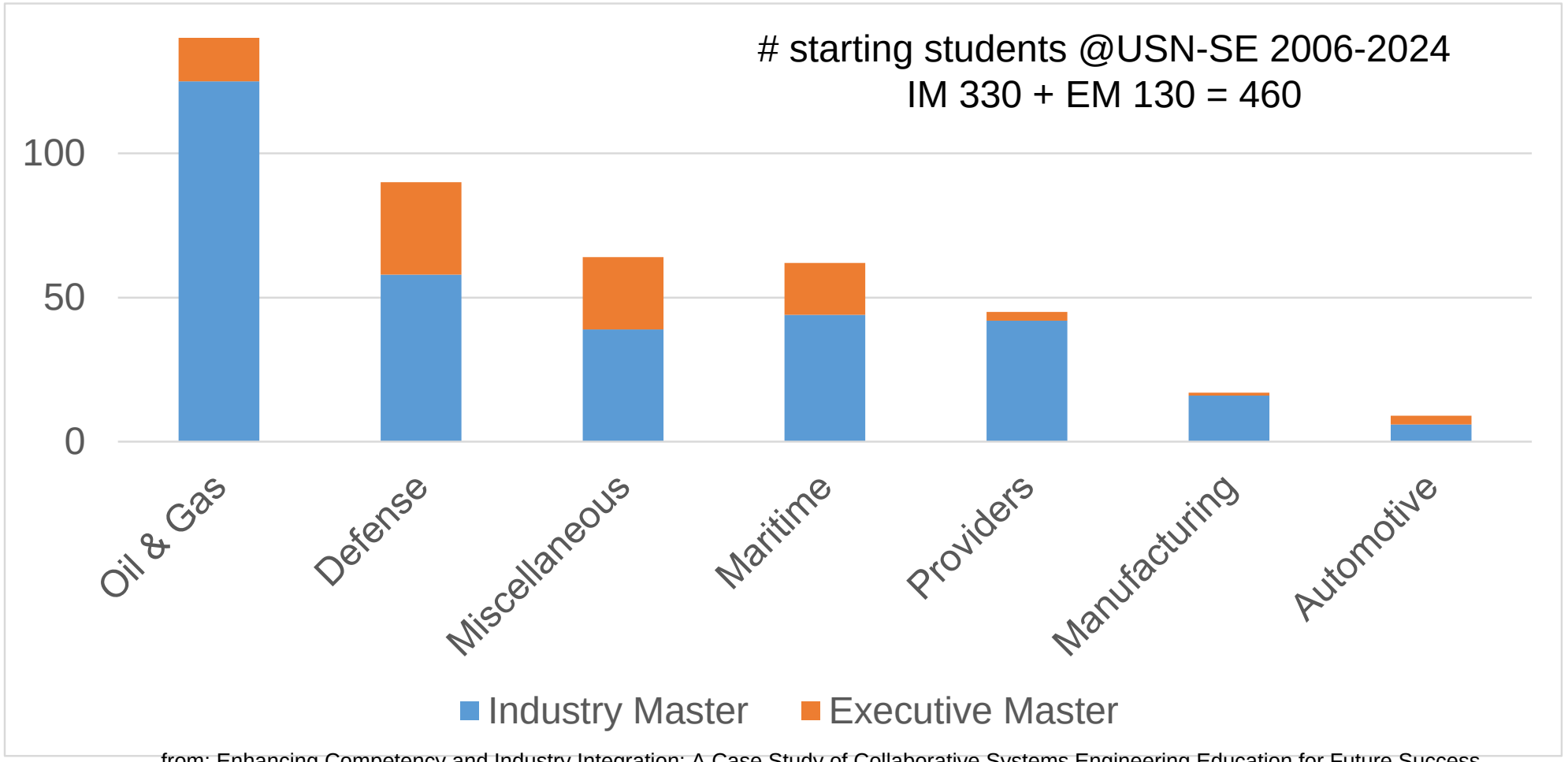
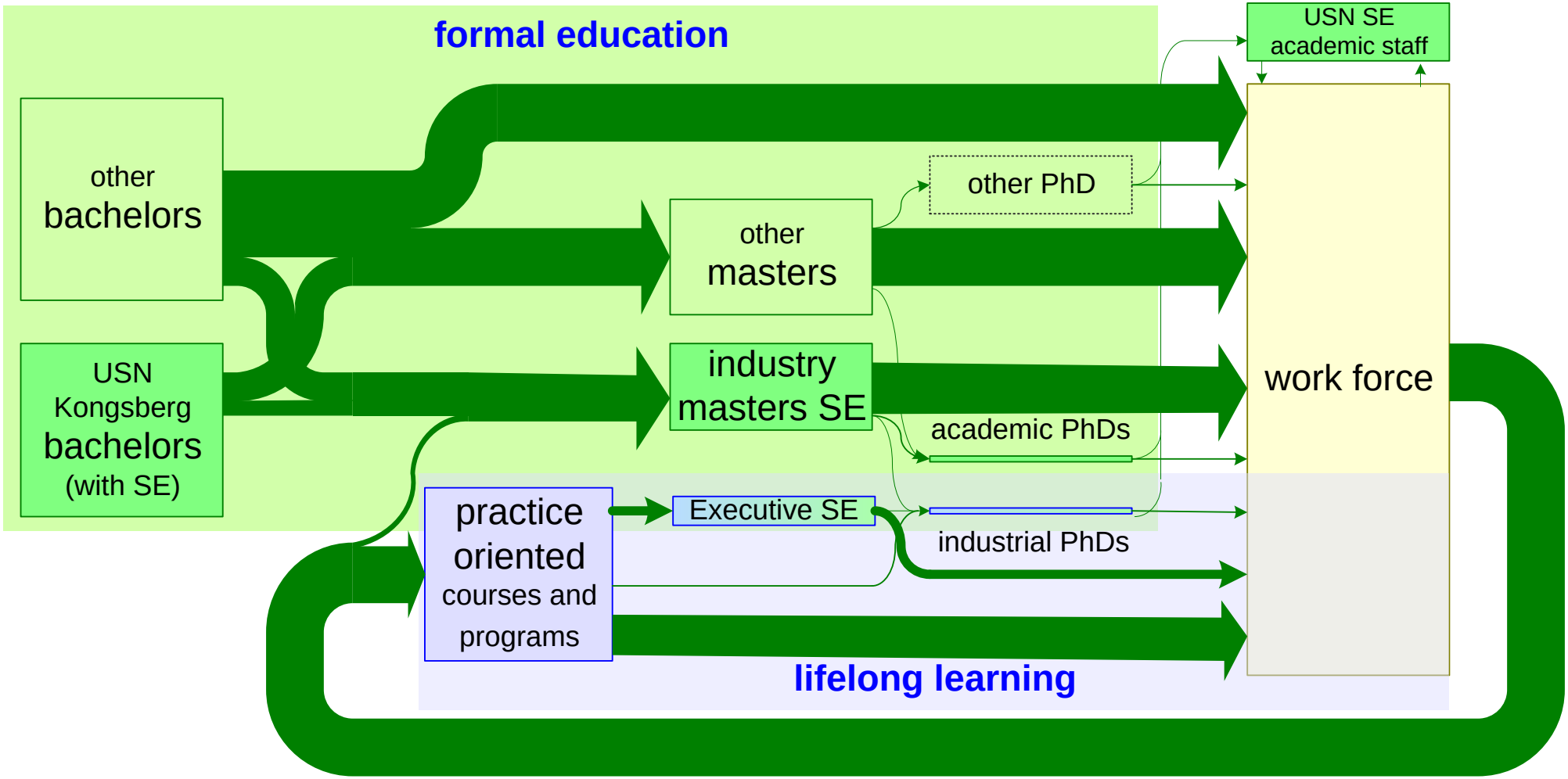


University of South-Eastern Norway (USN): SE Master



from: Enhancing Competency and Industry Integration: A Case Study of Collaborative Systems Engineering Education for Future Success
Omid Razbani, Gerrit Muller, Satyanarayana Kokkula, and Kristin Falk, MDPI Systems 2023, 11(9), 463; https://www.mdpi.com/2079-8954/11/9/463/pdf

Educational Pathways, There are many Paths to Rome

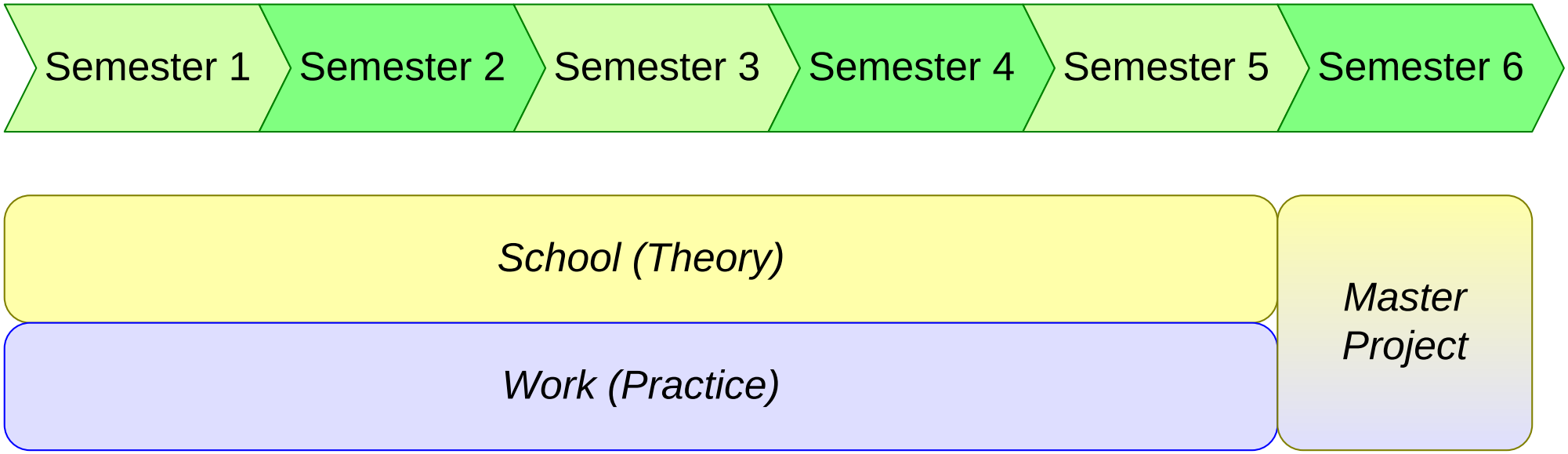


Vision behind the Industry Master

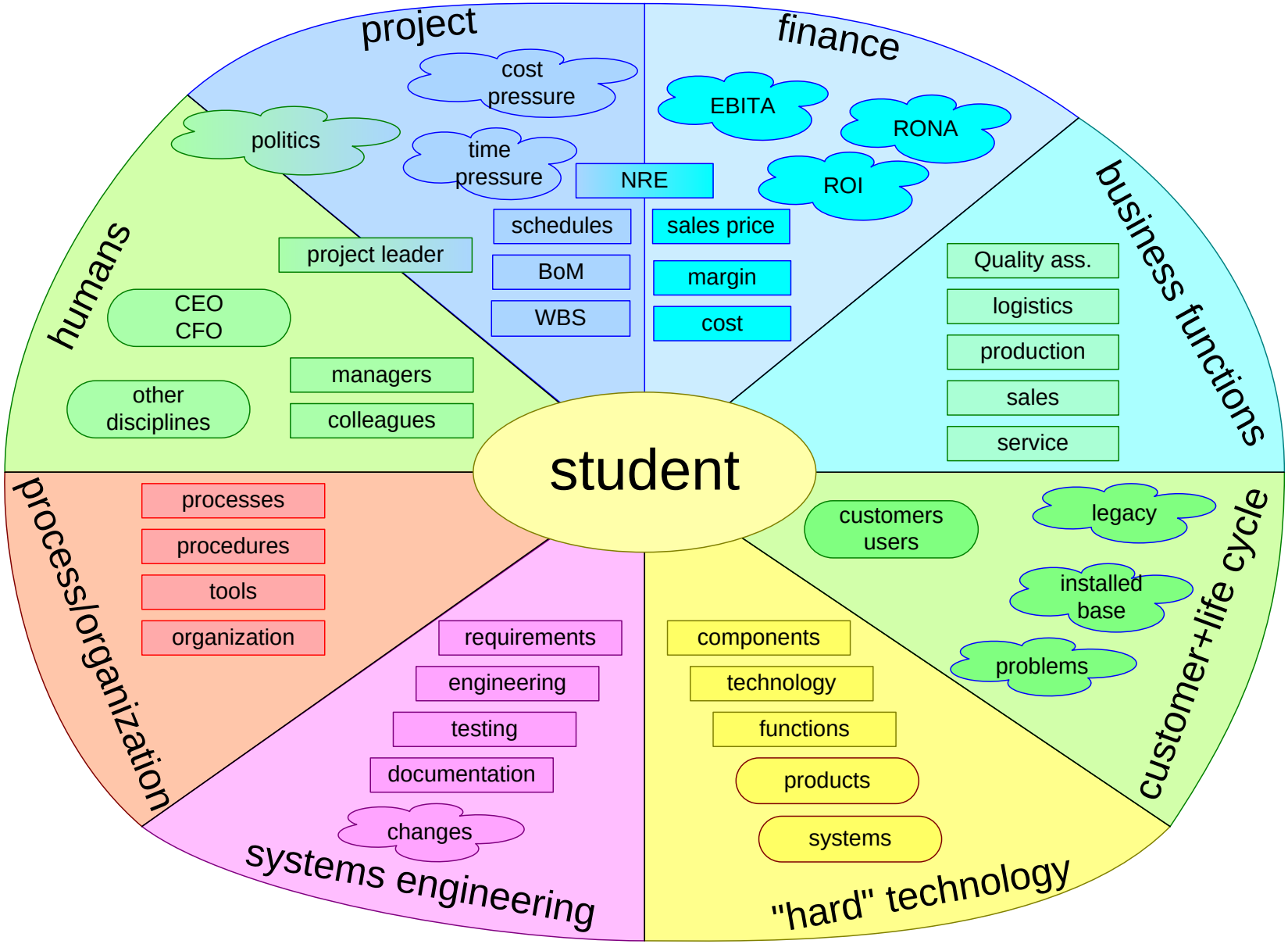
The objective of the industry master in systems engineering is to **accelerate** the **competence development** of new systems engineers, from e.g. 10..20 years in the past to 5..10 years.

Core of the acceleration is **experiential learning**, where offering **theory** and building up **experience** happens **concurrently** and is used to **reinforce learning**.

Work and Study Concurrently



Overload of Impressions for Fresh Bachelors



What is Competence?

Attitude (perseverance, faith, critical, constructive, etc.)

train

Ability (know when to use what skill and knowledge)

apply/use often, experience

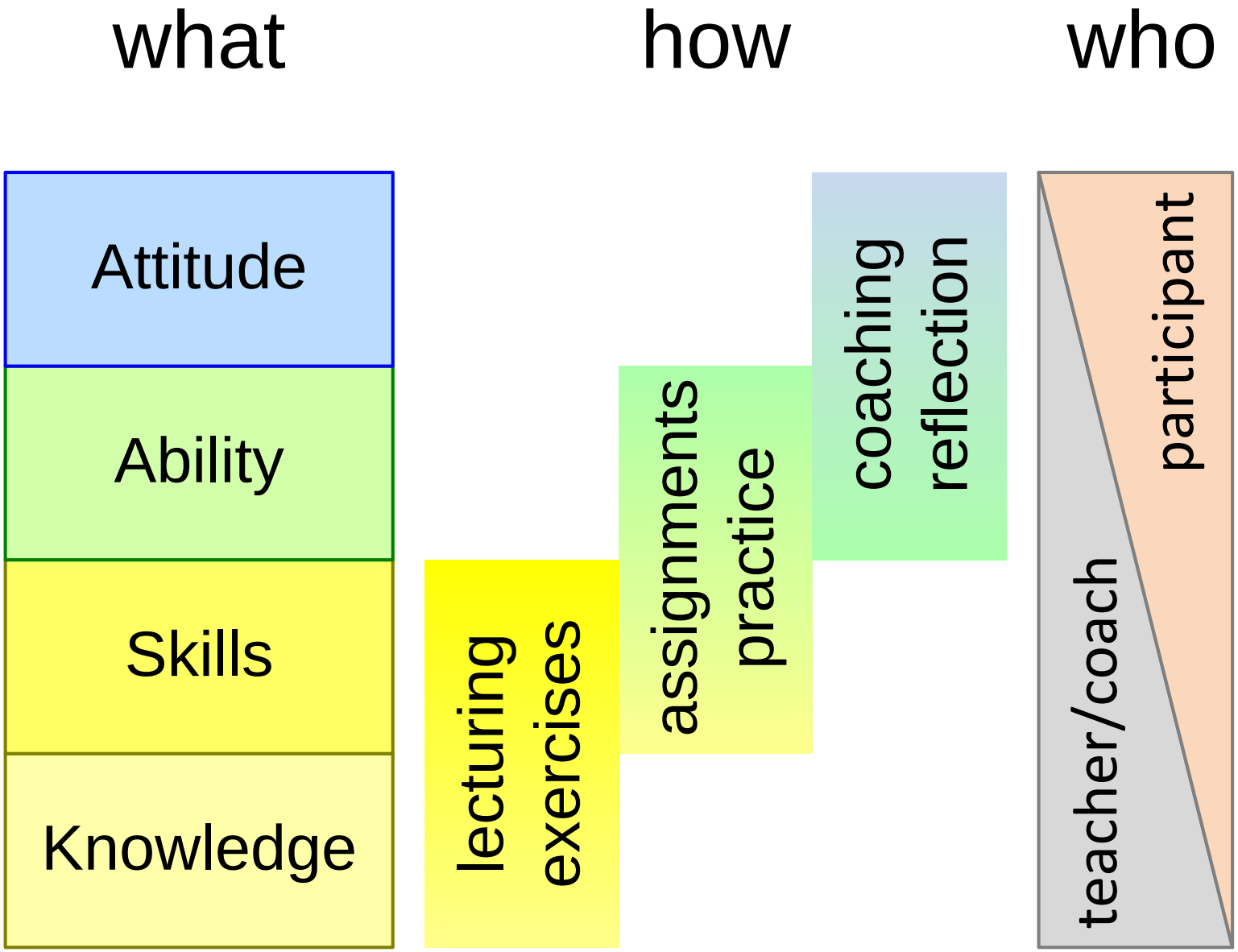
Skills (calculate missing angle, calculate hypothenusa)

exercise

Knowledge (triangle has 3 corners, sum of angles is 180 degrees, Pythagoras $c^2 = a^2 + b^2$)
learn

Competence = Knowledge + Skills + Ability + Attitude

Systems Competence mostly requires Ability and Attitude

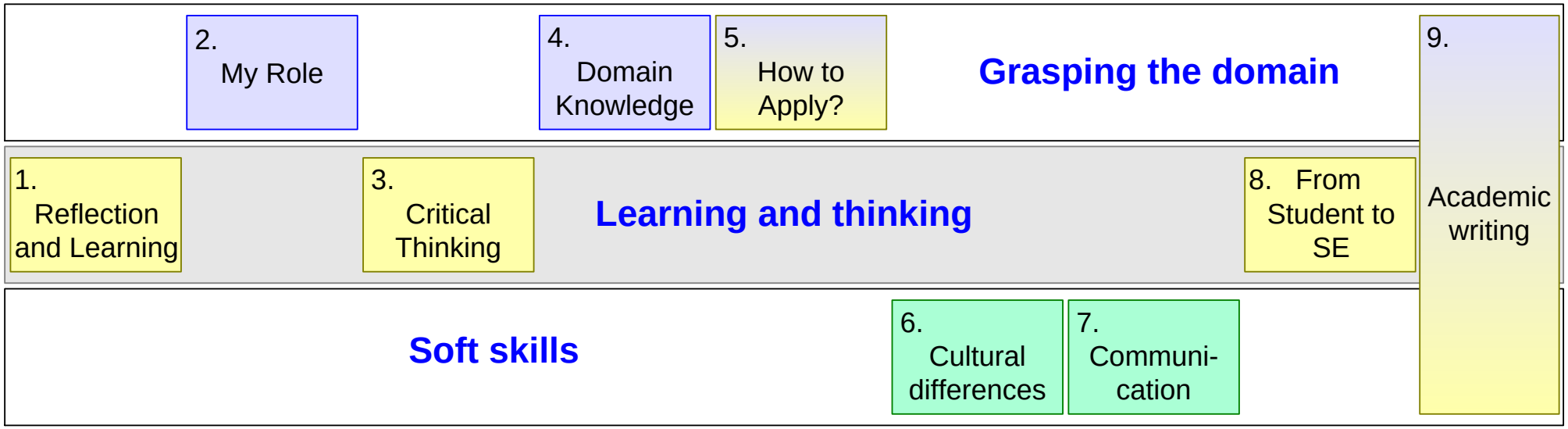


Course Format and Pedagogic

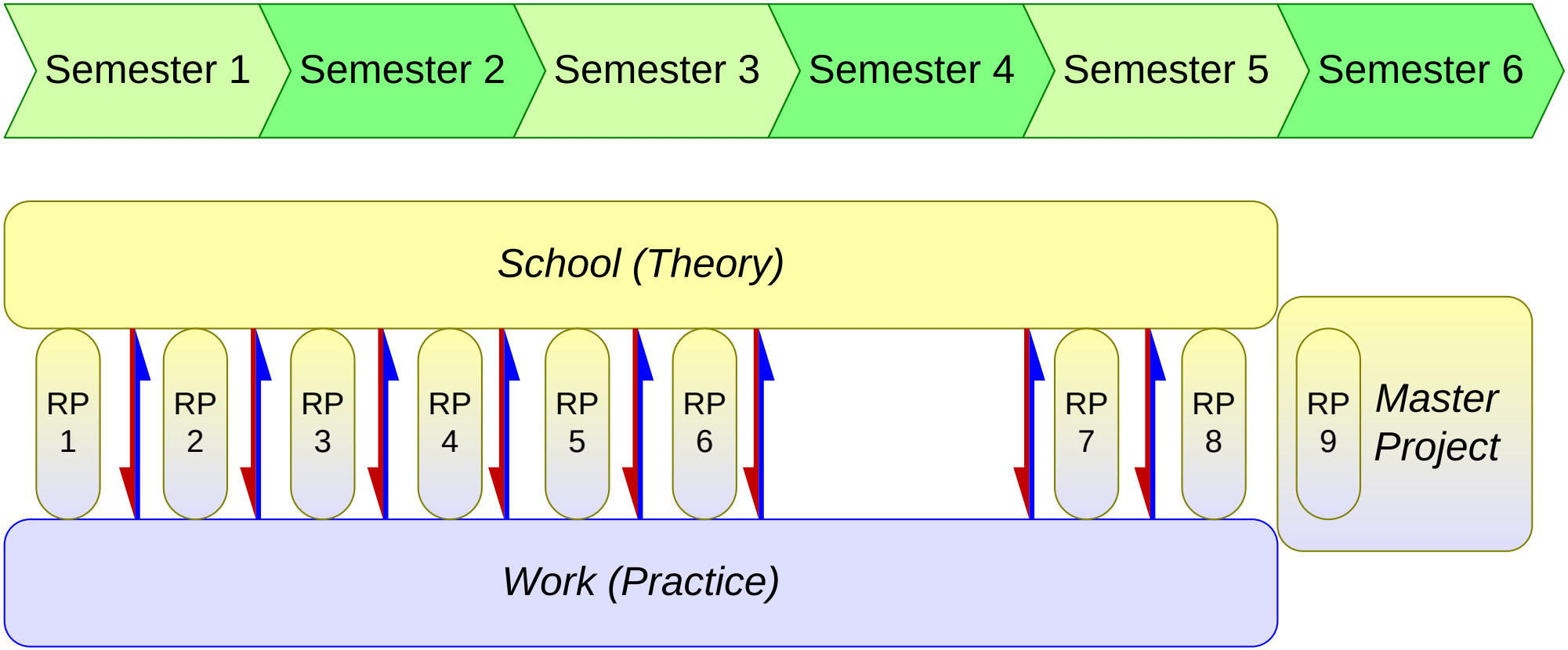
Prepare	*Intense course*	*10 week homework assignment*
e.g. reading or online	lecturing, discussion, and in-class group work	case-based, individual or group work, with supervision
0 to 20 hrs.	40 hrs.	140 to 160 hrs.

- Students travel 3 to 6 times per year
- Study and work planning is flexible
- Active learning, case-based
- Actual industry cases are possible (depends on course)

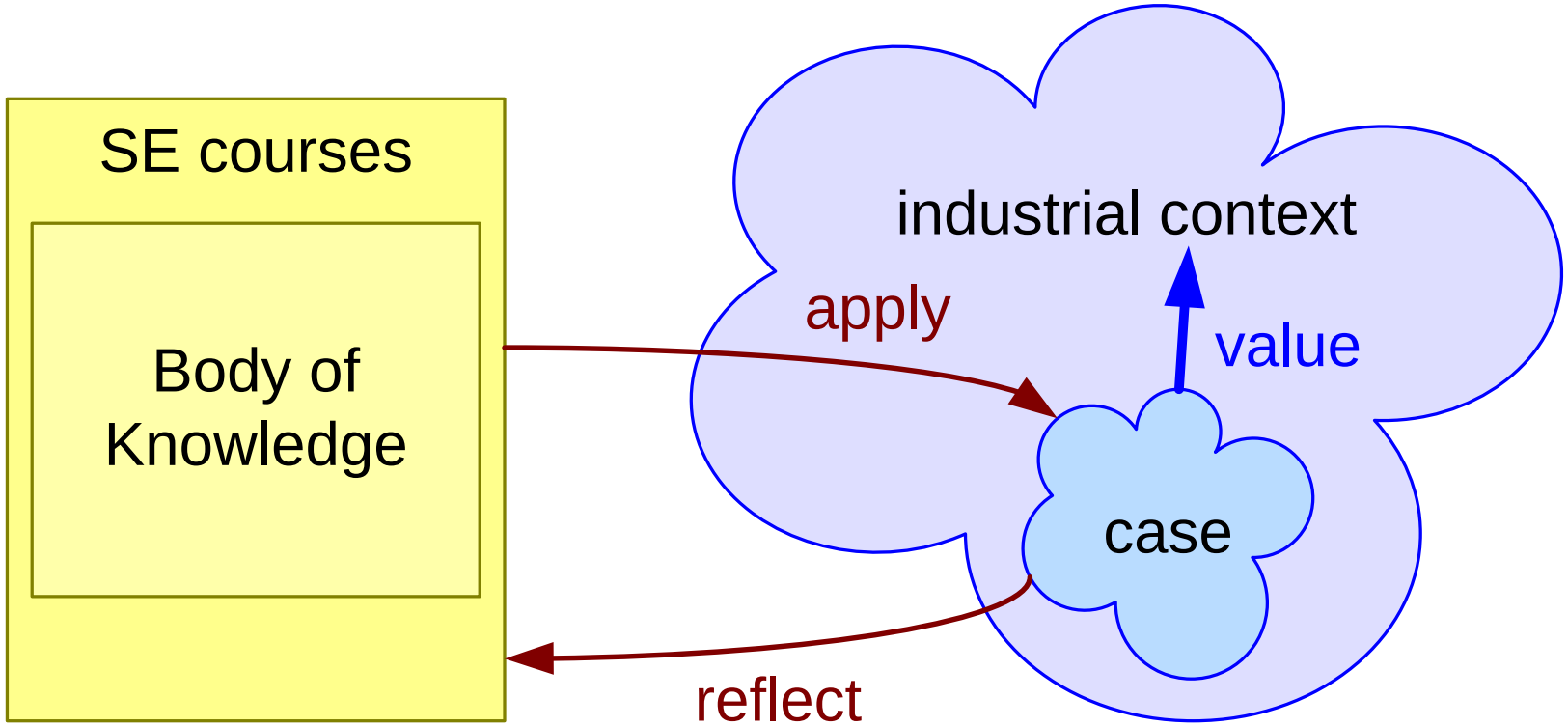
Reflective Practice; 9 Workshops in 3 Years



Reflective Practice Connects Study and Work



Objectives of Master Project



Apply part of the SE body of knowledge in practice and **evaluate** and **reflect** on its application, while **providing value** to the industrial sponsor

Embedding the Program in Industrial Networking

formal boards

strategic decision makers

Industrial Advisory Board

tactical subject matter experts

Reference group

operational HRM

HR forum

events

KSEE
June

SESG
November, February

Xmas party

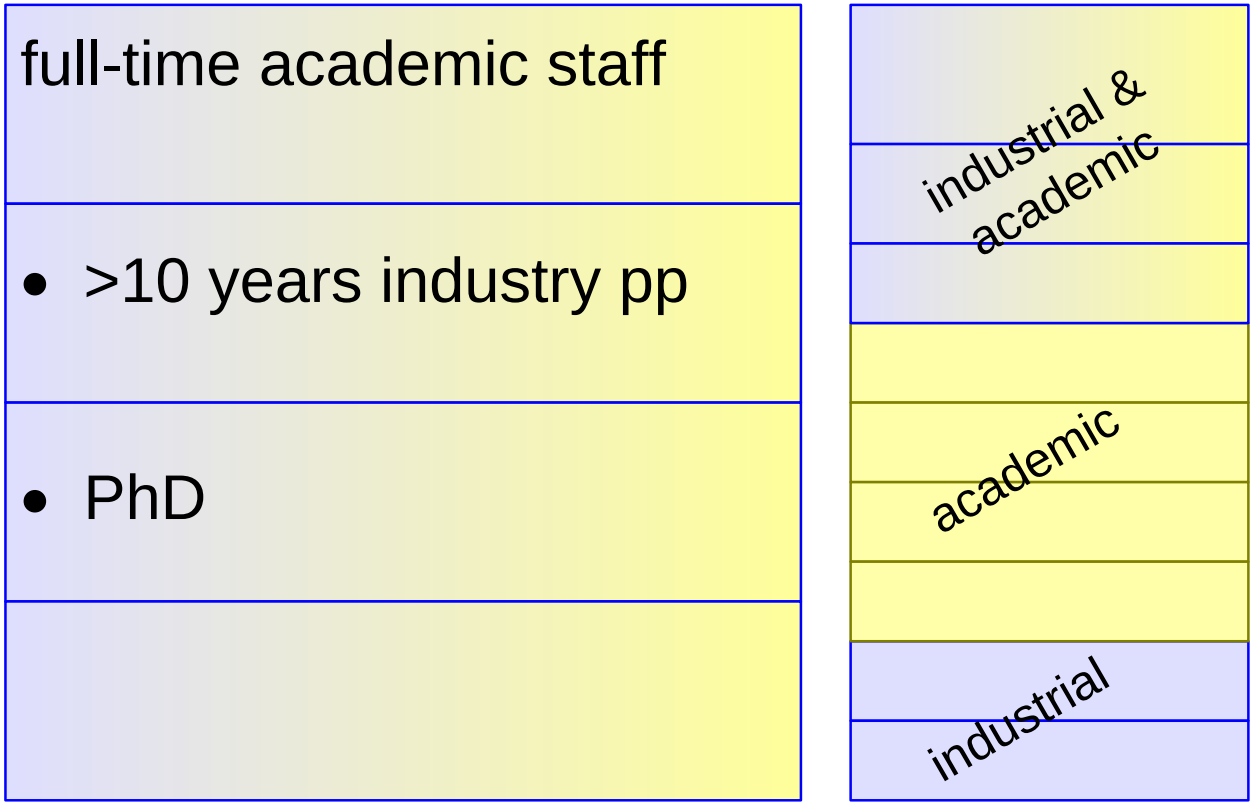
Research & Education

in-company courses

research

and a large amount of informal contacts

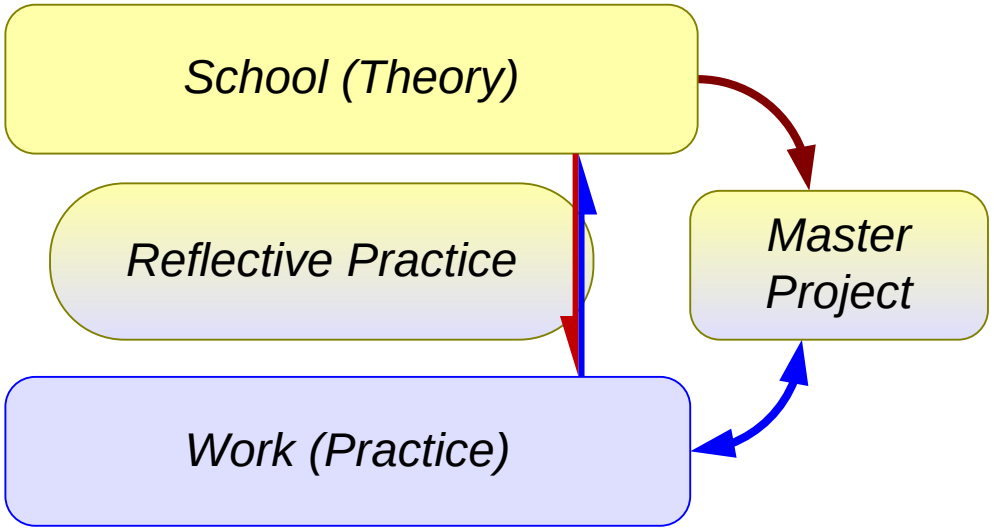
Challenge: Recruiting Industrial and Academic Staff



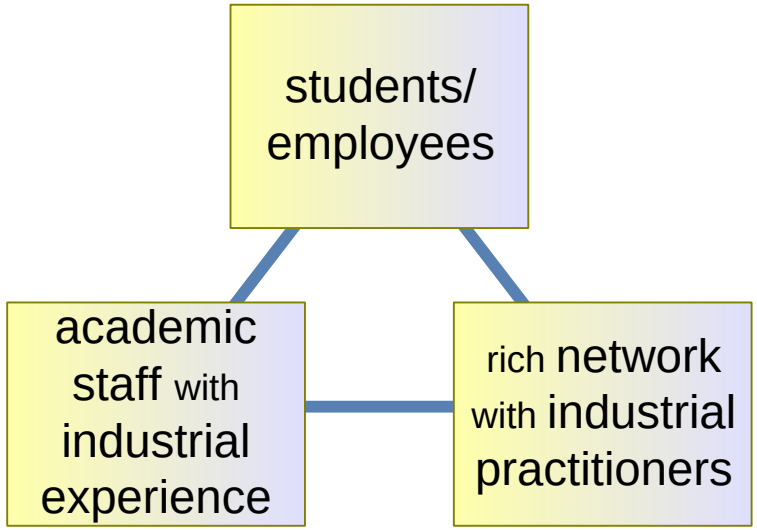
part-time academic staff

- highly experienced
- recognized
- broad coverage

Summary

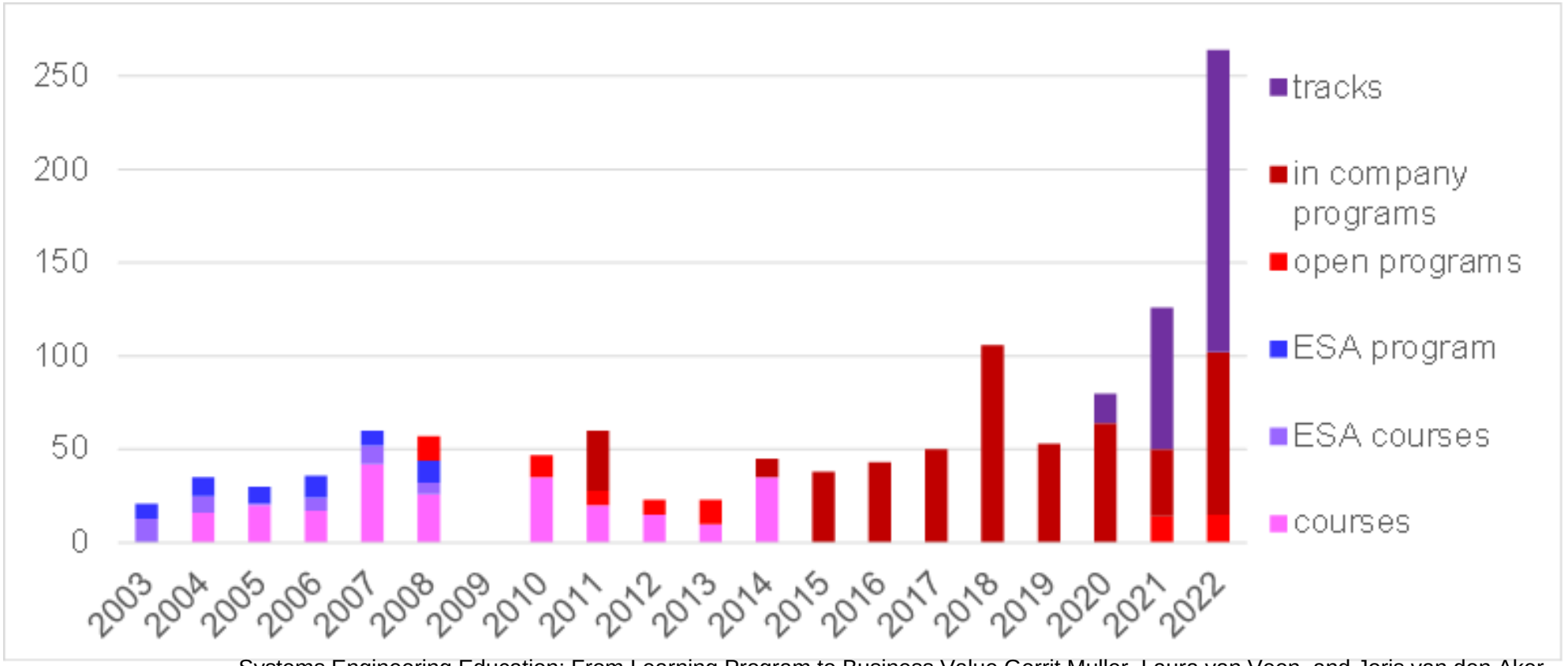


Studying and working concurrently
Format and pedagogic of courses fits industry
Reflective Practice connects study and work
The master project is the closure



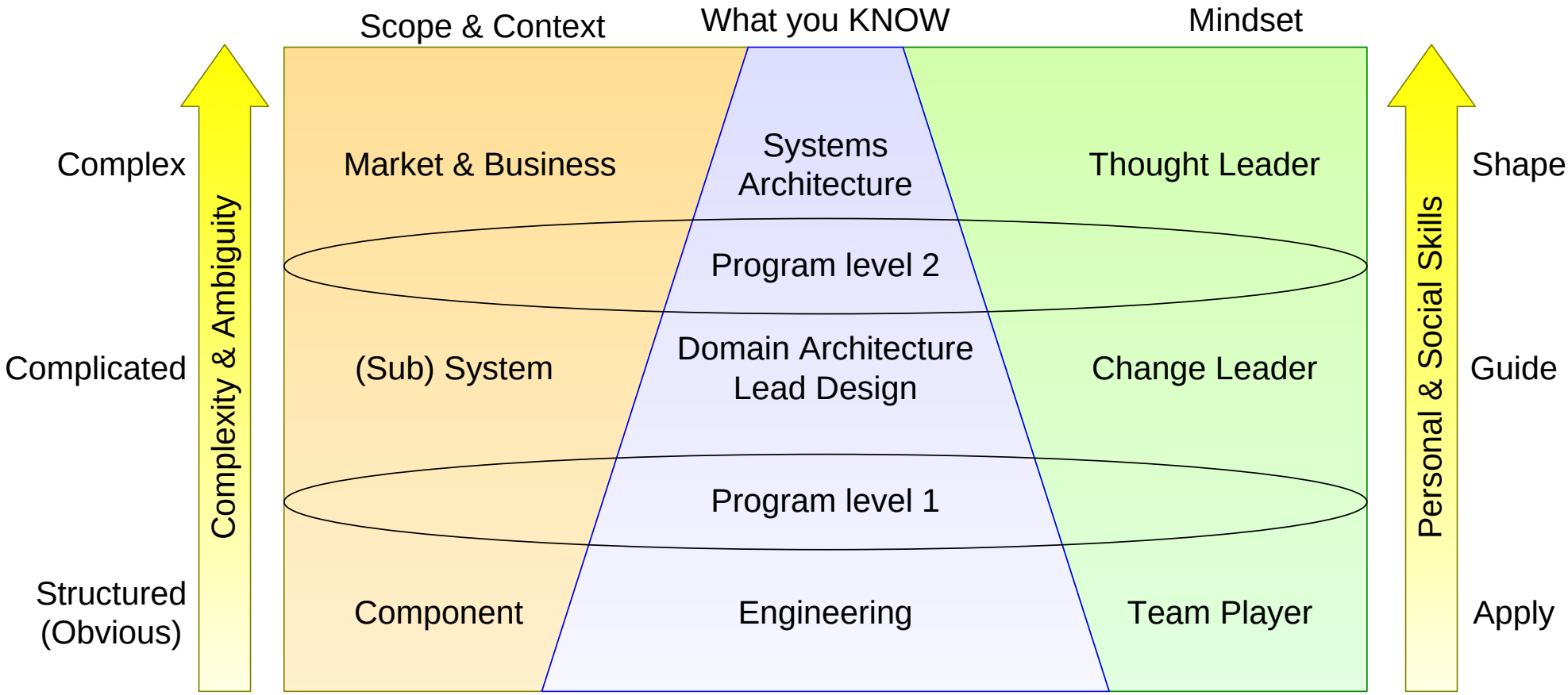
Continuous investment in industrial relations
Offering an inspiring environment and network
for practitioners, students, and staff

TNO-ESI Systems Education Participants



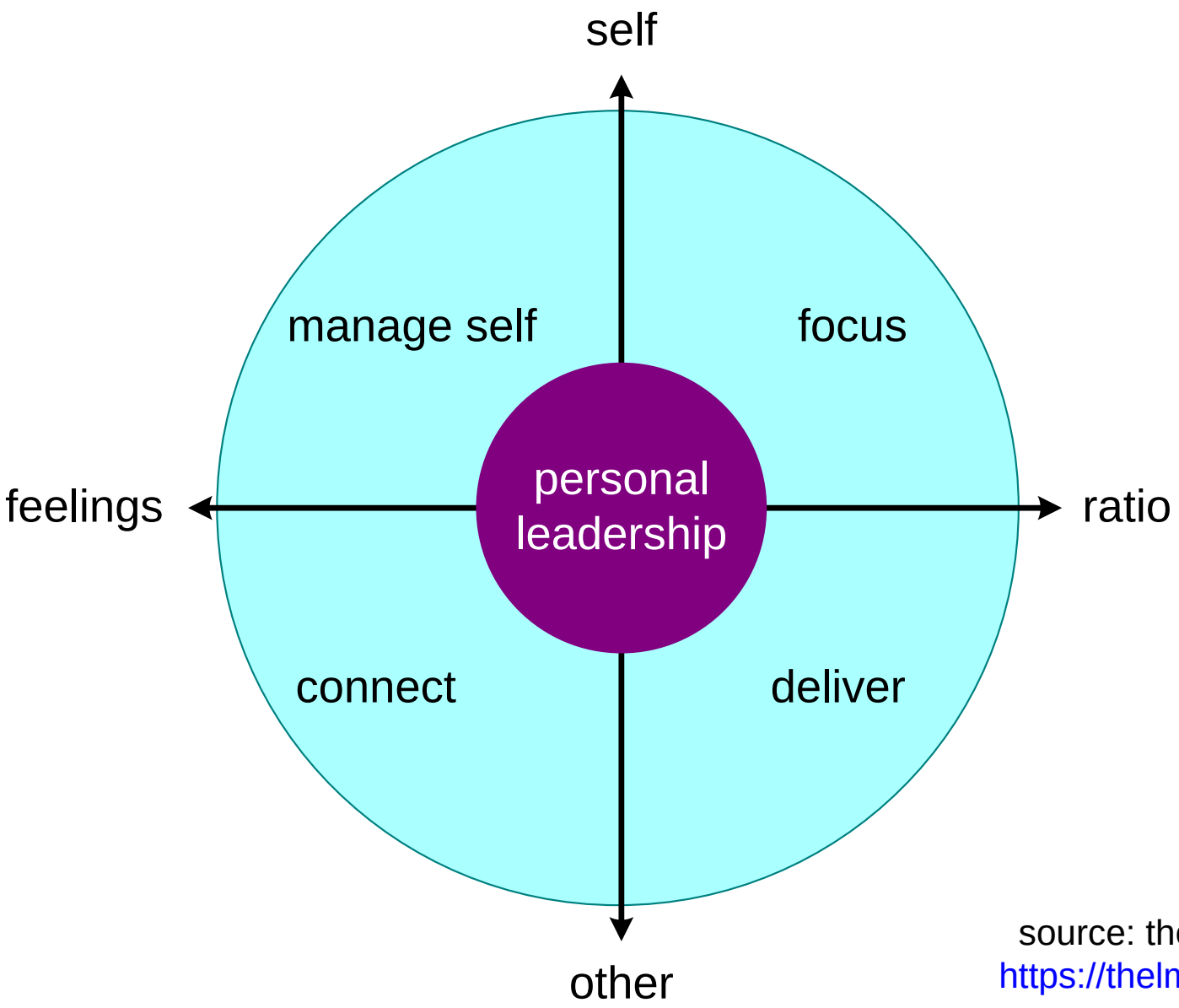
Systems Engineering Education: From Learning Program to Business Value Gerrit Muller, Laura van Veen, and Joris van den Aker
MDPI Systems 2023, 11(10), 510; https://www.mdpi.com/2079-8954/11/10/510/pdf

TNO-ESI Systems Education Model



Systems Engineering Education: From Learning Program to Business Value,2023,
Gerrit Muller, Laura van Veen, and Joris van den Aker https://www.mdpi.com/2079-8954/11/10/510/pdf

Leadership is the Key to Increase Systems Effectiveness



source: the LMS group
https://thelmsgroup.nl/en/

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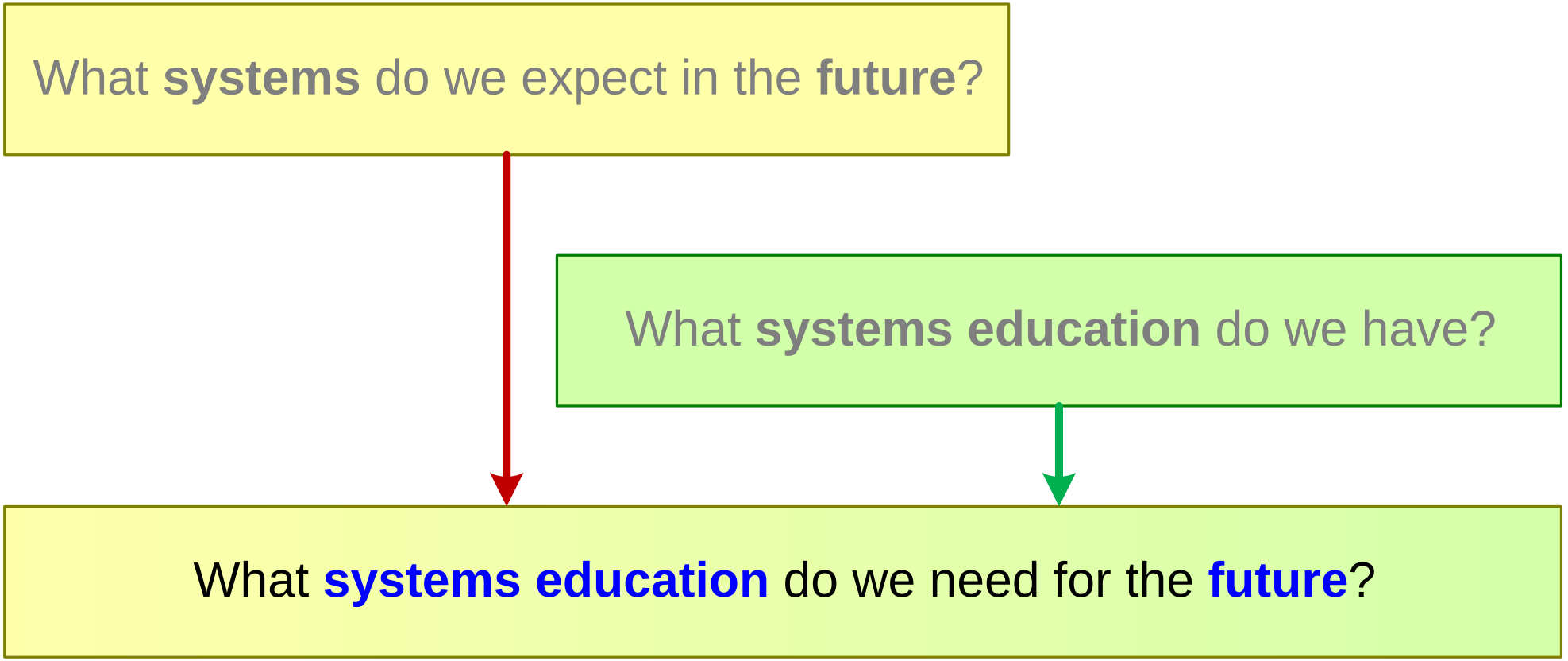

What Competences do We Need to Offer for Future Systems?

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Mitigation of System Trends

- socio-technical cyber-physical SoSs
- extensive ecosystems
- complexity due to humans and organizations
- sustainability
- security
- digital technologies
- many more technologies

leadership & professional competencies

fundamental societal skills (PESTEL)

depth education “playing with”

Propositions

- we have to educate **organizations**, not only **individuals**
- each system architect is a **unique individual**
- education needs to be **flexible to fit** individuals and organizations
- individuals learn architecting in **practice**
- therefore they need **reflection and coaching**; learn to learn
- architects must be **fast learners** to absorb domain and technology knowledge

Conclusions

Keep learning by refreshing, doing, and playing

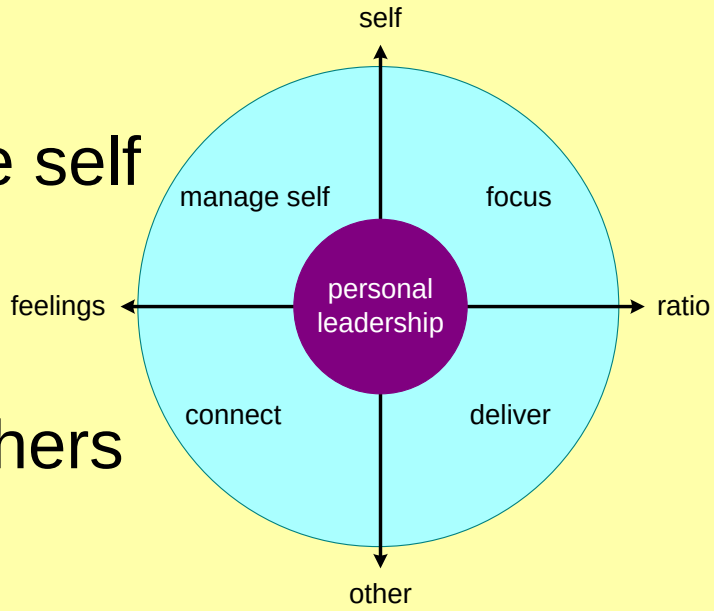
Adapt the **learning to** your and your organization's **needs**

Leadership is the biggest enhancer for content-full architects

manage self

to

lead others



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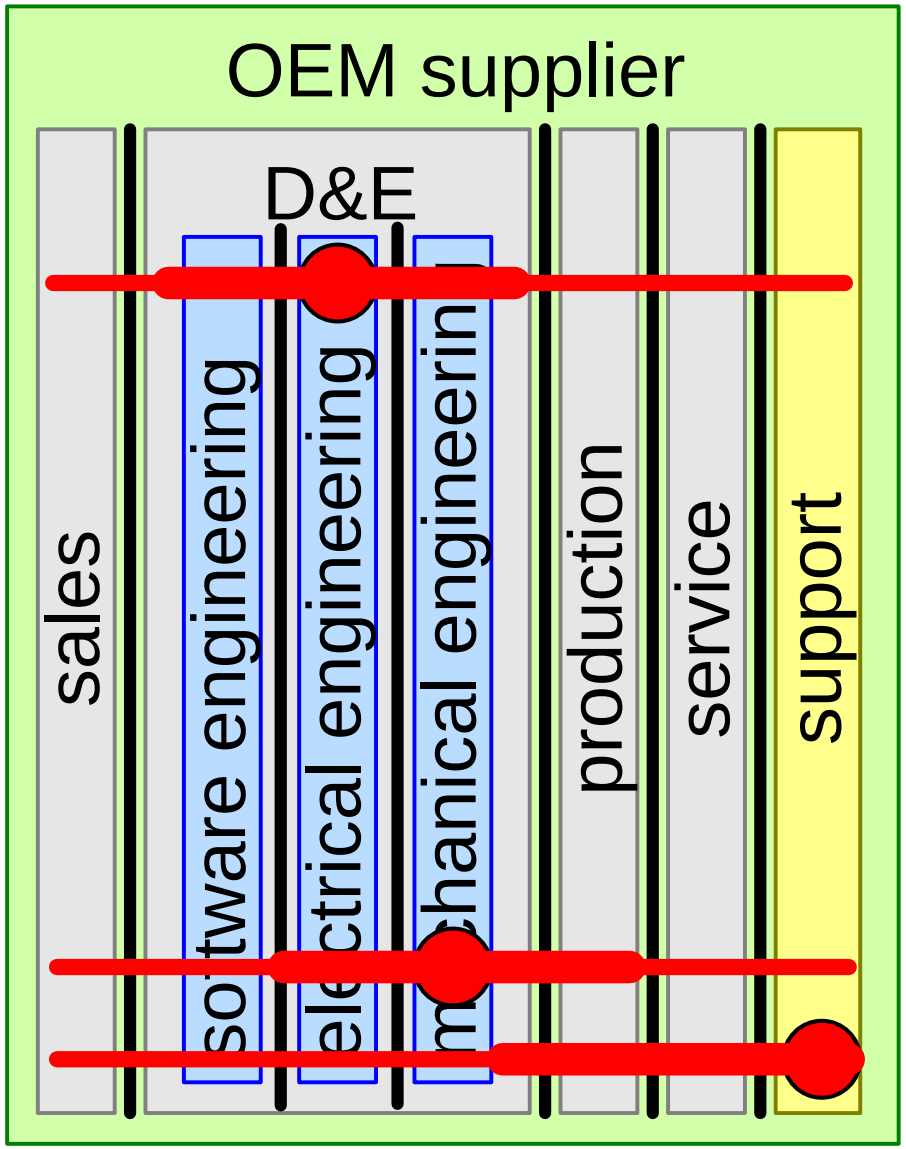
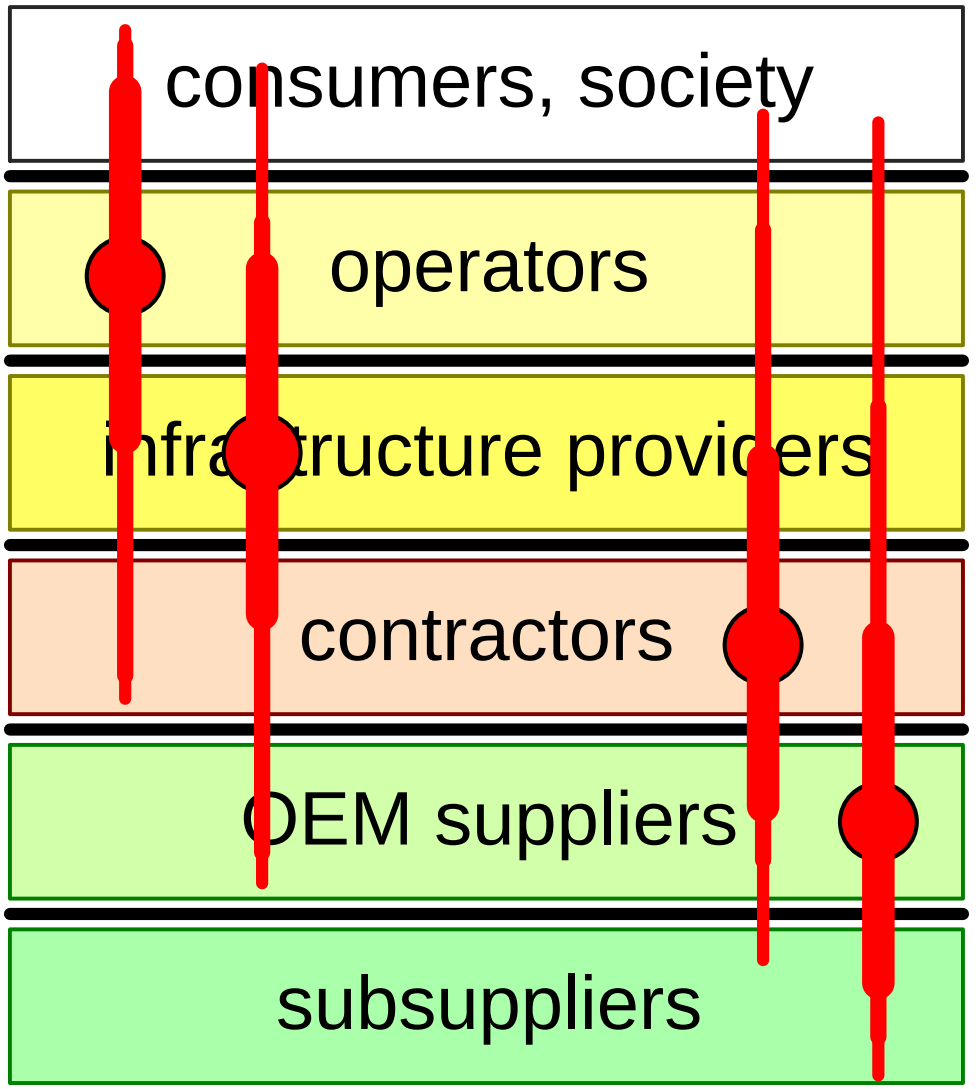
Can generative systems design solve the flaws of MBSE?
Oluf Tonning, KSEE 2024

https://www.gaudisite.nl/KSEE2024_Tonning_GenerativeSystemsDesignForMBSE.pdf

Architects Need Orchestration Competency





Capability Architecting