International Council on Systems Engineering
A better world through a systems approach

Teaching Systems Engineering for Students – Experiences from the Swedish Education System

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The INCOSE SE vision

In the INCOSE SE vision a key area identified is education.

Educational opportunities are perceived as lacking for SE.

Previous works discussing SE education find several challenges in the academic setting, but also success stories.

This paper

In this paper we provide our experiences of managing a 5-year systems engineering program.

We specifically focus on the Swedish context and discuss the paper through this lens.

We go through challenges, and success stories of managing a program.

Program website (in Swedish)

Some notes about the program

The title of the program is roughly: “Master of science in **dependable systems**”. We have tried to rename the program to systems engineering but not gotten positive receptions from the university to do this.

Håkan is the strategic program coordinator, while I act as the operative program coordinator.

The program has been active for ~10 years.

I am an alumni of the program!

Swedish national regulations

Higher education in Sweden is nationally regulated, with learning outcomes defined for subjects at the national level (e.g, engineering).

Pre-defined program types, traditional bachelor and master, in addition to Swedish variants with different requirements.

The Swedish “Civilingenjör” (roughly master of science) is a 5-year track, with increased emphasis on societal concerns, independence, creativity, teamwork, etc.

State of education

Swedish higher education is primarily funded through government, and universities are government bodies (i.e., politically steered to a large degree).

Universities are "paid" by the state depending on the performance of students, i.e., passing through courses.

Engineering students are generally more expensive due to labs and equipment, while also being among the lowest graduation rates (around 25-30% of 5-year program students graduate on time).

Engineering education is therefore somewhat unpopular for universities to fund due to high expenses per student, and often low return.

The program

	Year 1		Year 2		Year 3		Year 4		Year 5
Semester 1	Vector algebra 7.5 credits, first cycle	Systems engineering in context, 7.5 credits, first cycle	Measurement engineering 7.5 credits, first cycle	Statistics 7.5 credits, first cycle	Quality engineering 7.5 credits, first cycle	Information security 7.5 credits, first cycle	Embedded systems I 7.5 credits, second cycle	Control theory 7.5 credits, second cycle	Dependable systems project course, 30 credits, second cycle
Semester 2	Programming 7.5 credits, first cycle	Basic electronics 7.5 credits, first cycle	Human factors in systems 7.5 credits, first cycle	Architectures and communications for embedded systems 7.5 credits, first cycle	Electrical measuring systems 7.5 credits, first cycle	Material sciences 7.5 credits, first cycle	Embedded systems II 7.5 credits, second cycle	Safety-critical systems 7.5 credits, second cycle	
Semester 3	Single variable calculus 7.5 credits, first cycle	Applied CAD 7.5 credits, first cycle	Object oriented programming 7.5 credits, first cycle	Physics I 7.5 credits, first cycle	Scientific methods, science and ethics 7.5 credits, first cycle	Autonomous vehicles, 5 credits second cycle	Design of autonomous systems 7.5 credits, second cycle	Programming of dependable embedded systems (DVA494), 7.5 credits, second cycle	Master Thesis work – Dependable systems, 30 credits, second cycle
Semester 4	Electronic systems 7.5 credits, first cycle	Embedded systems programming 7.5 credits, first cycle	Multi variable calculus, 7.5 credits, first cycle	Require-ments engineering 7.5 credits, first cycle	Development of safety-critical systems 7.5 credits, first cycle	Robust electronics 10 credits, first cycle	Model based development, 7.5 credits, second cycle	Design of fault-tolerant systems 7.5 credits, second cycle	

☐ Systems engineering related courses

The program

Some notes;

- Computer science & embedded systems main.
- Originally a 3-year aerospace program.
- Flexible course offering.
- Overlapping with robotics program.

	Year 1		Year 2		Year 3		Year 4		Year 5
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☐ Systems engineering related courses

Input for the program management

The program is developed together with local industry.

We invite industrial partners and alumni for bi-annual strategic meetings.

Due to the overlap with robotics, certain decisions are made in unison.

Some take-aways from the program

Staffing managed by cross-division teaching teams.

One class a year is admitted of ~30 students.

Students' progression is similar to other engineering programs.

All graduated students found relevant employment after graduation, often in roles relating to safety, security, researchers, etc.

Barriers

Learning by doing
The learning by doing paradigm is seen as important but can be challenging to achieve due to the large scope.

Intuitiveness of SE
It can be difficult to get an intuitive feeling for SE among students, leading to some reluctance.

SE requires time to learn
It is usually not until the final year that SE starts to become clear in the student's mind.

Non-tangible aspects of SE
There are rarely definitive answers, but often more soft, abstract, and ill-defined concepts to tackle.

SE is a holistic discipline
We need a large number of disciplines to be involved. Furthermore, courses need to concern larger problems and often group projects.

SE is about decision-making
Instead of solving well-defined problems, students are asked to motivate decisions.

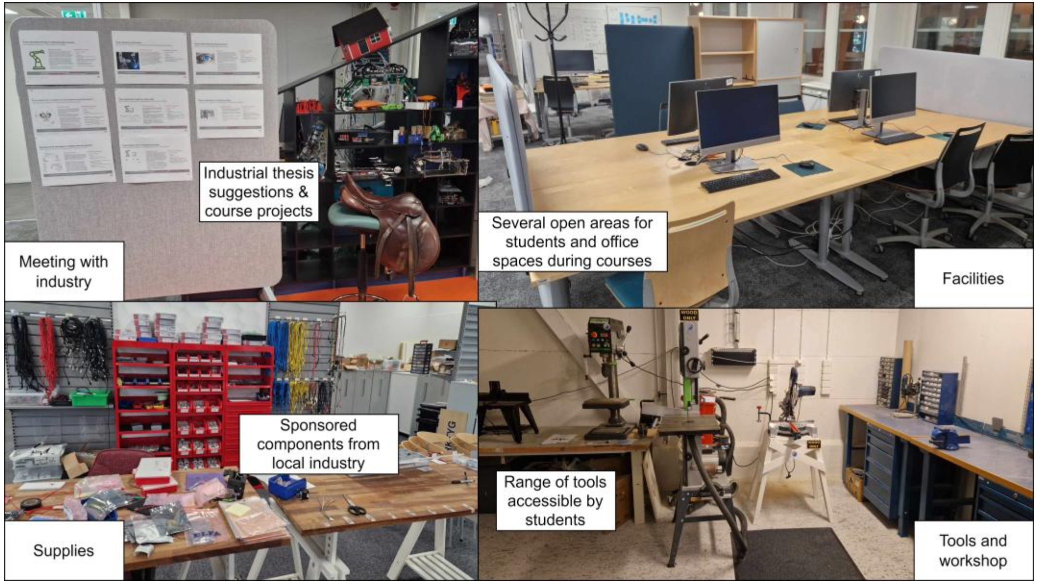
SE is not a widely recognized field of study
Difficult to convey clearly to both students and faculty as there is no previous recognition.

Principle 1: Students ownership of their own learning

We provide facilities where students can have “offices”.

Industrial practitioners often act as owners or stakeholders in projects.

We aim to provide the necessary tools and facilities to enable students to be creative and hands-on.



Principle 1: Students ownership of their own learning

The last year capstone project example; AutoSail.

Collaboration with other Universities.

Student-owned and student-driven.

Principle 2: Supporting the T-shaped engineer

Our program follows the principles of a T-shaped engineer, meaning a broad base and focus on a few topics.

To some extent, this view of engineering is enforced via national regulations, but we try to go a step further.

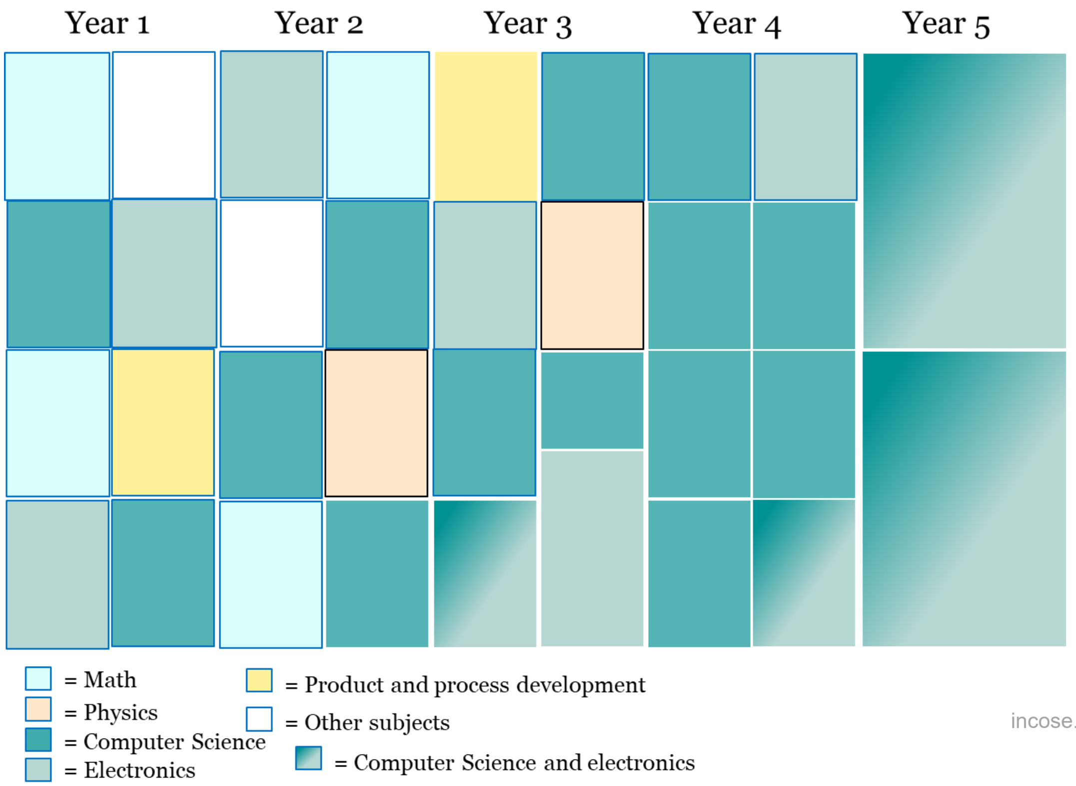
This includes involvement of faculty from other fields, such as psychology, in addition to different engineering disciplines.

Principle 2: Supporting the T-shaped engineer

Flavors of different sciences in each of the courses.

Often several are impacting at once.

SE belongs in the computer science group due to its formal classification.



Principle 3: Industrial pressence in education

We aim to include industrial collaboration to the extent possible in courses.

On the basic level, this includes guest lectures, but we encourage and strive for joint projects with students and industry.

In the final year students do a half year collaborative project with industry, in addition to a master thesis which most of the time is done together with a company.

Principle 3: Industrial pressence in education

Årskurs 1

	Årskurs 1	Samverkan
HT 2022	Kursnamn Ingenjörsvetenskap för robotik och tillförlitliga system, OAI103	
	Kursnamn Vektoralgebra, MAA051	
	Kursnamn Programmering, DVA117	
	Kursnamn Elektronik grundkurs, ELA105	
VT 2023	Kursnamn Envariabelkalkyl, MAA048	
	Kursnamn Tillämpad CAD, MTA103	
	Kursnamn Elektroniksystem, ELA211	
	Kursnamn Programmering för inbyggda system, DVA270	

Årskurs 2

	Årskurs 2	Samverkan
HT 2023	Kursnamn Mätteknik, ELA213	
	Kursnamn Sannolikhetslära och statistisk teori, MAA137	
	Kursnamn Mänskliga faktorer i tekniska system, OAI104	
	Kursnamn Arkitektur och datakommunikation för inbyggda system, DVA271	
VT 2024	Kursnamn Objektorienterad programmering, DVA222	
	Kursnamn Mekanik 1, MFY006	
	Kursnamn Flervariabelkalkyl, MAA152	
	Kursnamn Kravhantering, DVA274	

Årskurs 3

	Årskurs 3	Samverkan
HT 2024	Kursnamn Kvalitets-, och underhållsteknik, PPU309 (GCV02)	
	Kursnamn Informationssäkerhet, DVA252 (GCV04)	
	Kursnamn Elektriska mätsystem, ELA212 (GCV04)	
	Kursnamn Farkoststrukturer och materiallära, FYA017	
VT 2025	Kursnamn Autonoma farkoster, DVAXXX, FLA433	
	Kursnamn Information, kunskap, vetenskap och etik, DVA305 (GCV04)	
	Kursnamn Robust elektronik för tillförlitliga system, ELA305 (GCV02)	
	Kursnamn Utveckling av säkerhetskritiska system, DVA344 (GCV04)(FLA310 GCV02)	

Årskurs 4

	Årskurs 4	Samverkan
HT 2025	Kursnamn Inbyggda system I, DVA454	
	Kursnamn Reglerteknik, ELA410 / ELA415	
	Kursnamn Inbyggda system II, DVA482	
	Kursnamn Säkerhetskritiska system, DVA437	
VT 2026	Kursnamn Design av autonoma system, DVA485	
	Kursnamn Programmering av tillförlitliga inbyggda system, DVA494	
	Kursnamn Modellbaserad utveckling för tillförlitliga system, DVA484	
	Kursnamn Design av feltoleranta system, FLA432	

Årskurs 5

	Årskurs 5	Samverkan
HT 2026	Kursnamn Projekt i tillförlitliga system, DVAXXX (GCV04), FLA402 (GCV02)	
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VT 2027	Examensarbete tillförlitliga system, FLA500	
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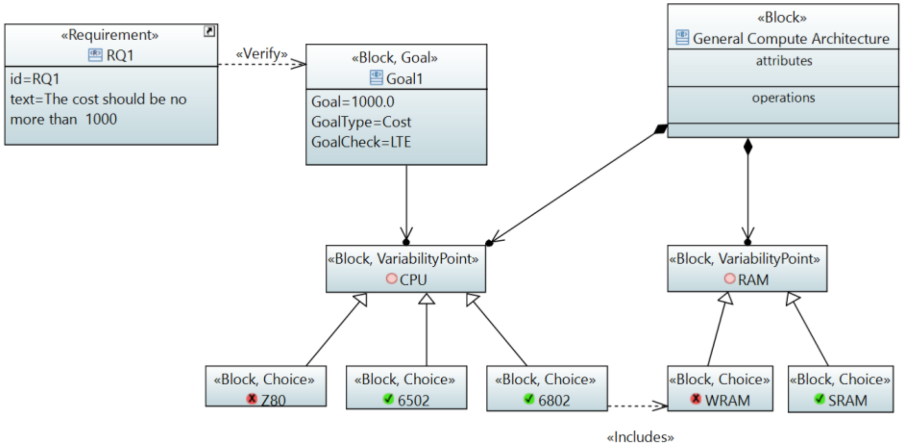
Principle 4: Connection with research and future technology

To enable connection with research and future technology, we often encourage course owners to include aspects of research in the courses.

We also include academic writing and peer-review processes from the start of the program.

Inclusion of AI, model-based engineering, and other areas of future technology.

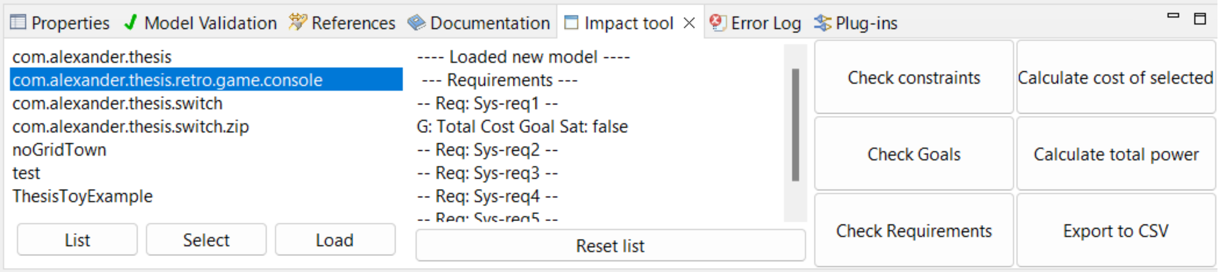
Principle 4: Connection with research and future technology



Student thesis example; Integrating a model-based approach for variability management in a company.

Evaluating user receptions through quantitative research methods.

Making solution open-source.

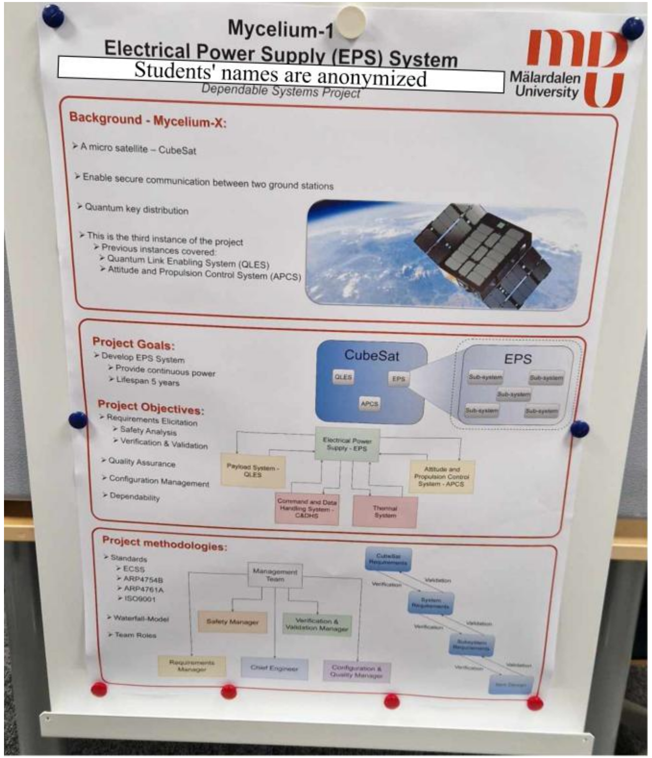


Principle 5: Communication as a core skill

We encourage communication as a core skill, and most courses include some form of oral communication.

Peer-review and seminars among students are employed in many courses to let them train on constructive feedback.

The figure demonstrates a poster for a final year project, presented for invited industrial partners.



Discussion

- Our program is looking for partner programs, please reach out to me or Håkan: hakan.forsberg@mdu.se
- Going forward, the program will continue to change based on input from industrial partners.
- We see a lot of success in the collaboration across other programs and parts of the University.
- The Swedish higher education system limits the ability to construct a SE program freely.

Conclusion

- We have presented our current version of a SE 5-year program in Sweden.
- We see challenges in creating opportunities for SE education but also see that students who graduate appreciate the education.
- We hope to continue to develop the program going forward to be a useful SE education!

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