
Kongsberg, Norway

GENERAL INFORMATION

TITLE OF THE CASE	Master in Systems Engineering
SALES PITCH	An example of close industry-academia integration to facilitate competence development for innovation using the systems engineering framework. This is an excellent example of collaboration between working life and academia, both at institutional and study program level, which in turn facilitates higher quality and more relevant education.
ORGANISATION	University College of Southeast Norway
COUNTRY	Norway
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AUTHOR(S)	Gerrit Muller, Leif Naess & Silja M. Sverreson
NATURE OF INTERACTION	[ ] Collaboration in R&D [ ] Academic mobility [ ] Student mobility [ ] Commercialisation of R&D results in science [X] Lifelong learning [X] Curriculum development and delivery [ ] Entrepreneurship [ ] Governance [ ] Other (please specify)
SUPPORTING MECHANISM	[ ] Strategic instrument [X] Structural instrument or approach [ ] Operational activity [ ] Framework condition

CASE STUDY PROFILE

1. SUMMARY

Norwegian industry and government identified systems engineering as a strategic competence. They formed a Norwegian Center of Expertise Systems Engineering (NCE-SE) in Kongsberg in 2005. One of the specific results of the NCE-SE is the startup of a master in systems engineering program at the university college in Kongsberg. This master program uses a unique cooperation and study model: students work mandatory in industry during their study allowing them to combine theoretical and practical perspectives.

This paper reports the results of applying this educational model between 2006 and 2017. In this period, 308 students started their SE study. The chance of succeeding in the IM program is quite high. Only six of the 191 students that graduated stopped, seven students needed more than the three-year program, and four students needed more time. The success of the program inspired the university college to expand the industry master model to other studies. The so-called Industry Academy has the ambition to roll out similar educational models for more studies.

2. BACKGROUND

The need for generating systems engineering competence has evolved since industrial enterprises require interdisciplinary understanding to develop increasingly complex solutions to their customers. To achieve this, they require senior personnel with significant engineering experience and an interest in a holistic approach to systems development. Considering experience-based knowledge can take a decade or more to develop organically, there are few experts in this field; a situation which creates a significant bottleneck for further innovation and development of the industry. One goal of systems engineering education is to shorten the time required to become a systems engineer. In the past, engineers evolved into systems engineers after 10-25 years of traditional engineering experience in specific disciplines.

The industry in Kongsberg started a Master Program in Systems Engineering in collaboration with USN, back in 2005.

This industry identified systems engineering as a common competence, which is a crucial competence in today's fast-paced world with increasingly complex systems. The objective of the NCE-SE is to develop the systems engineering competence, especially for Norwegian companies. Development of today's students into future systems engineers is one of the ways to achieve this objective.

NCE-SE started with a close cooperation with Stevens Institute of Technology, from Hoboken, NJ, USA. Initially, academic staff of Stevens flew in teaching the American master study in systems engineering as a Norwegian branch of their faculty. In a few years, USN built its own staff and got accreditation for the master in systems engineering in Norway.

3. OBJECTIVES

Prime business objectives are:

- To develop a more competent systems engineering industry in Norway compared to international standards.
- To decrease the time, it takes to develop a systems engineer of high quality, from 15-25 years to half of that time.
- To support the industry in their endeavor to innovate, remain competitive, and manage risks pertaining to the businesses

The key academic objective is:

- To integrate the systems engineering industry with academia to ensure the highest learning outcome for the students within the field

4. RESPONSIBILITY

Within the institute, we had a leadership team consisting of an institute leader, an operational manager, a research coordinator, and an academic program coordinator. The university college embedded the institute within a traditional academic hierarchic structure with a dean and a rector. The industrial cooperation happens in three boards: an industrial advisory board (strategic), a reference group (tactical; subject matter experts), and human resource managers (operational aspects).

IMPLEMENTATION & FUNDING

5. STRATEGY & ACTIVITIES UNDERTAKEN

The program is set up such that people in industry can follow courses without too much disruption of their daily work. The program teaches courses as 5-day intense courses, followed by a 10-week homework period. In this way, participants miss a few weeks per year for the courses, while they can do the homework when it fits their work schedule.

The program design follows the reference curriculum in systems engineering (GRCSE). A core of five courses and a master project is mandatory, leaving students with the freedom to select seven elective courses to tailor the study to their company's and individual needs. Students perform the master projects in the company where they work. They apply suitable systems engineering methods or techniques, which they must evaluate in academic fashion. This master project model brings value to the company, while it serves as research vehicle in systems engineering at the same time; this is the so-called industry-as-laboratory model (Potts).

One of the initial actions of the NCE-SE was the start of a master program in systems engineering. A major challenge of developing systems engineering competence is that this competence has a large experience component. In the past, "growing" systems engineers took 10 to 20 years. The goal of the master study is to half the lead-time for new systems engineers.

The university college in Kongsberg pioneered a new educational format, where students do mandatory work and study part-time, the so-called industry master. The idea behind this model is that students see practice, which provides them a better perspective for the theory. At the same time, this construction allows them to apply parts of theory in practice, facilitating learning by experience. The study supports the two-way interaction between theory and practice with a special course "Reflective Practice", inspired by the work of Kolb and Schon and documented in Merete R. Faanes' PhD-thesis.

The university college is now in the process of building a research group, to ensure that the competence of the university college is state-of-the-art.

The institute uses a strategy process with the following number of steps:

- Current State
- Internal Analysis
- External Analysis
- Issue Analysis (i.e. gap between external opportunities and internal constraints)
- Strategy Formulation (i.e. choices)
- Implementation Plan

The staff executed this process in 2011 and 2014. It repeats the same process in 2018. The Industrial Advisory Board, Reference Group and Human resource managers discuss the result of the strategy process.

In the period of this case study, the university college merged twice with other university colleges. The objective of the mergers is to create sufficient critical mass and academic quality to grow into a university. These mergers create opportunities and threats. Major threats are increase of bureaucracy, and an introverted (academic) focus hampering the close industry cooperation of the systems engineering master. Opportunities are the broader potential of the educational model for other study programs, and a broader research and innovation community.

6. MONITORING AND EVALUATION

The program uses a combination of formal and informal feedback. During courses, teachers collect feedback informally, allowing fast response. Students evaluate each course at the end with a standard evaluation form with 16 Likert scale questions and 3 open questions. The Likert scale questions are about the course and the teacher. At the end of the program, students evaluate the program. Finally, the university college monitors students' satisfaction across all programs.

In 2012, the industry was asked for feedback on the impact the students experienced whilst working in the industry and completing their master program in systems engineering at the same time. The industrial feedback was of great value by contributing to the strategy planning taking place at that time.

However, the program has yet to standardize feedback from the industry partners. Currently, the feedback from industry partners comes via the industrial advisory board, the reference group, and the human resource managers. In the end, this dialog secures immediate feedback and very fast improvements cycles of the program compared to traditional academic approaches.

7. SUSTAINABILITY MEASURES

The institute achieves long-term viability of the master by institutionalizing the industrial partnerships. The institute expands staffing to reach critical momentum. Building a research portfolio and filling a pipeline of PhD students is essential for the critical mass of the staff. The institute is currently still in the bootstrapping phase of the research and innovation build-up.

Major sustainability threat is the university college culture and the need to proof academic quality. University colleges are not used to close cooperation with industrial partners. The interdisciplinary nature of systems engineering fits poorly in the discipline-oriented organizations. The systems engineering leadership is still searching for measures to cope with this risk.

8. COSTS

The educational model based on experiential learning is staff intensive. Small classes are necessary to facilitate active discussion with teacher feedback. Case-based homework requires significant supervision. The staff that is capable of teaching in this way is scarce, since it requires significant industrial experience in combination with an academic foundation and teaching affinity. For the teaching and mentoring part of the program, Table 1 shows the estimated number of hours per year the staff is spending on various activities.

Table 1 includes a critical activity for the program: managing the industrial partnerships. The partners need a long-term perspective and partnership. Yearly, the institute and partners need to arrange sufficient positions for students and match individual students to specific positions. Both activities from the contribution industry contacts.

Program in Systems Engineering	# hours
14 courses comprising 187 hours each	2 848
Reflective Practice courses	230
Mentoring students with their Master Project	1 225
Industry contacts	1 688
Administrative hours	1144
Total	**6 835**

Table 1: The distribution of the number of hours the staff is spending each year on a typical cohort of 25 students.

9. FUNDING

National and local governments and industry jointly funded NCE-SE with equal contributions for 10 years. NCE-SE funded the master programs in the initial years. The program currently has a few main funding streams:

- Standard government funding, based on study seats for expected number of starting students, produced study points, and number of graduating students; this is the main income
- National and local government agencies provide project-based research funding. In some projects industry funds part of the research too.
- Consultancy projects and In-company courses generate additional income

In general, the standard government funding is just sufficient to cover the educational model and the necessary research and competence development of the staff. The industrial income via external courses and consultancy at our Industry Partners are necessary to run the model. Main challenge is to bootstrap the research activity and funding.

OUTCOMES & IMPACT

10. OUTCOMES

Figures 1 and 2 show the influx of students and the number of graduating students per cohort. The success rate for IM students is high: at this moment 132 of 141 students graduated, i.e. 93.6%. Figure 3 shows the study duration for the Industry Masters and Part Time students. Of the 132 graduated IM students 94.6% graduated in the nominal three years or faster. Part-time students show much more variation in their study duration.

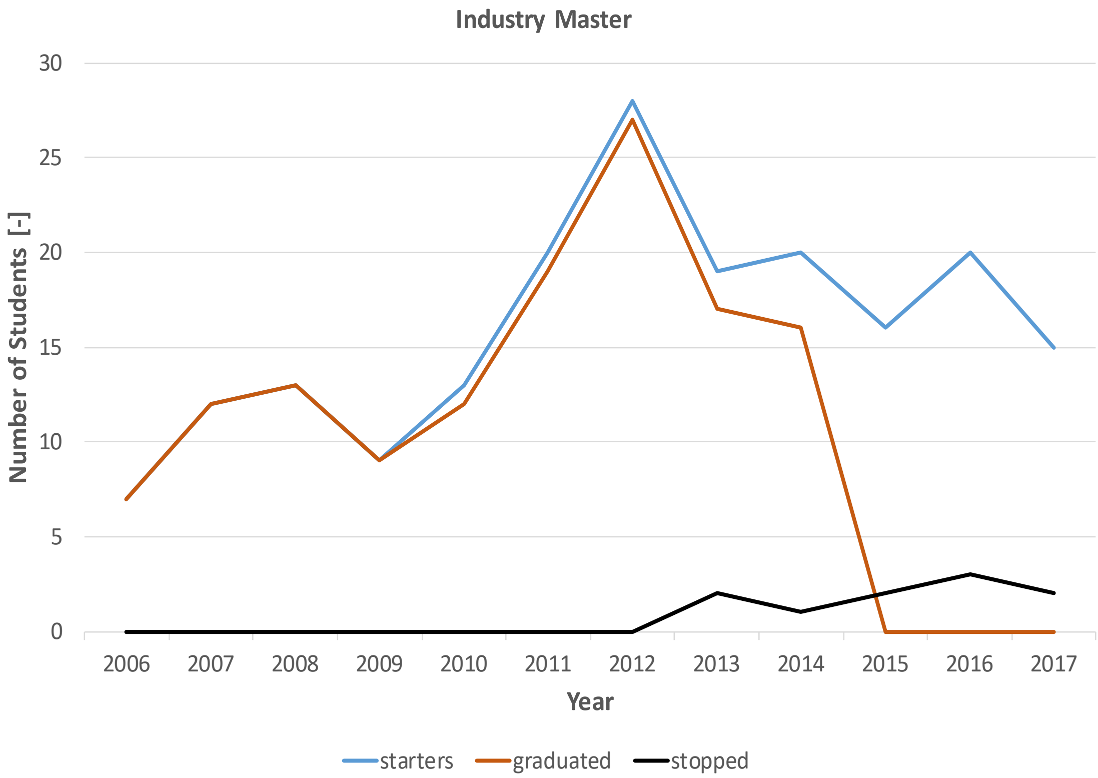

Figure 1: Influx and graduation of Industry Masters

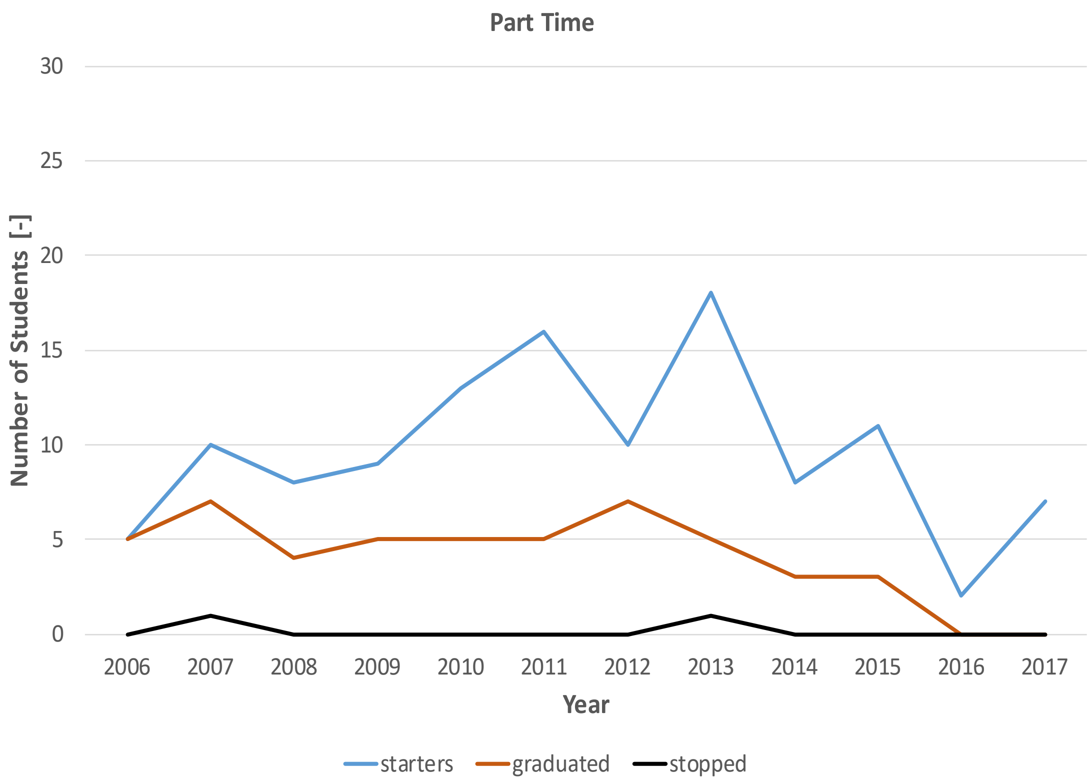

Figure 2: Influx and graduation of Part Timers

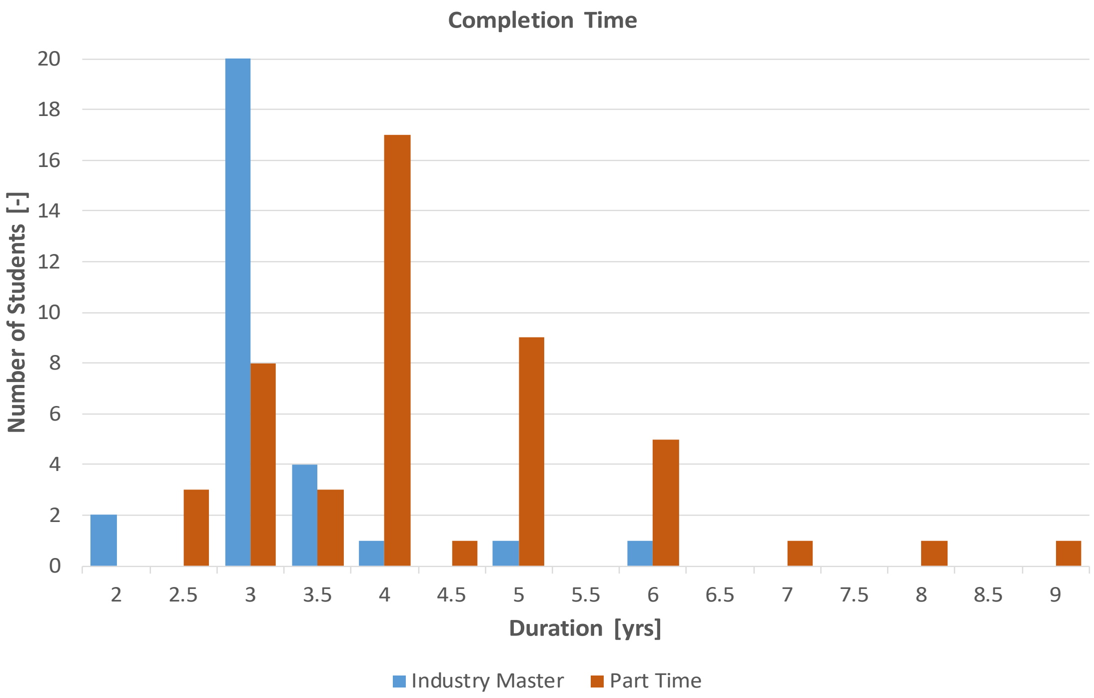

Figure 3: Completion time of Industry Masters and Part Timers

Students work in about 60 companies in a wide variety of domains. Figure 4 shows the most dominant domains. The Oil and Gas industry is by far the largest, followed by defense and maritime. Miscellaneous is a combination of diverse domains, such as engineering, OEM equipment, education, and transport.

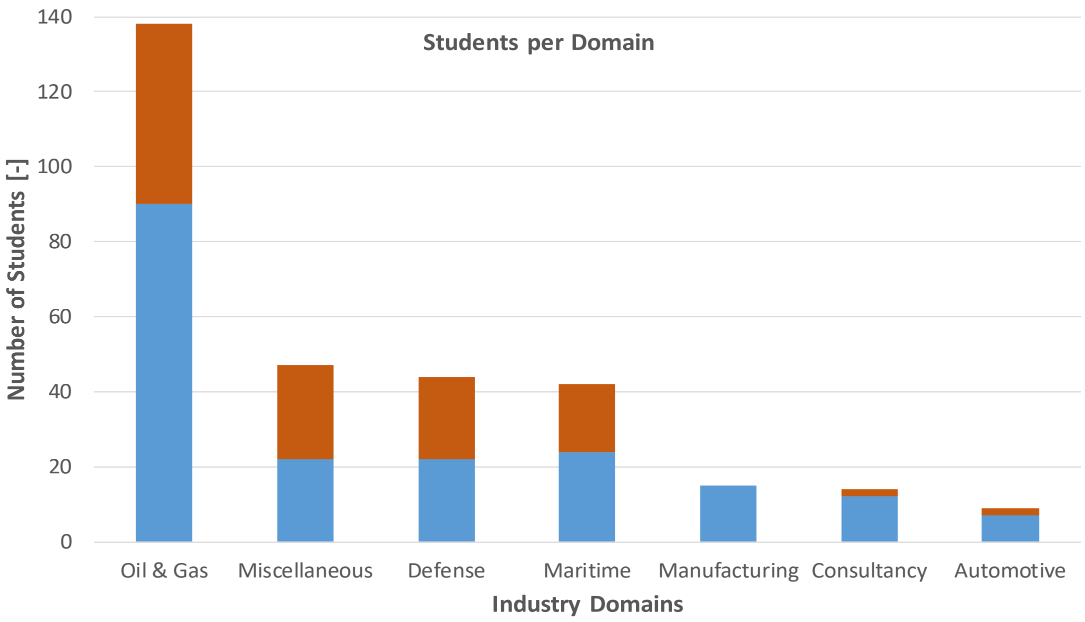

Figure 4: Student distribution across Industry Domains

The dependency on a few main domains allows the institute to cope with similar issues in industry. It can integrate these issues in the learning material. At the same time, the dependency on a few main domains makes the institute model vulnerable for market fluctuations. Figure 5 illustrates this by showing the oil price and the number of IM students in the oil and gas domain in the same graph. The institute countered this effect by expanding the industry partners into other domains. However, Figures 1 and 2 show the number of students still suffers from the oil price crisis that started in 2014. On a general note, this industrial reality also exposes academia to the very same market forces and is, thus, a strength of the viability of industry-academia integration.

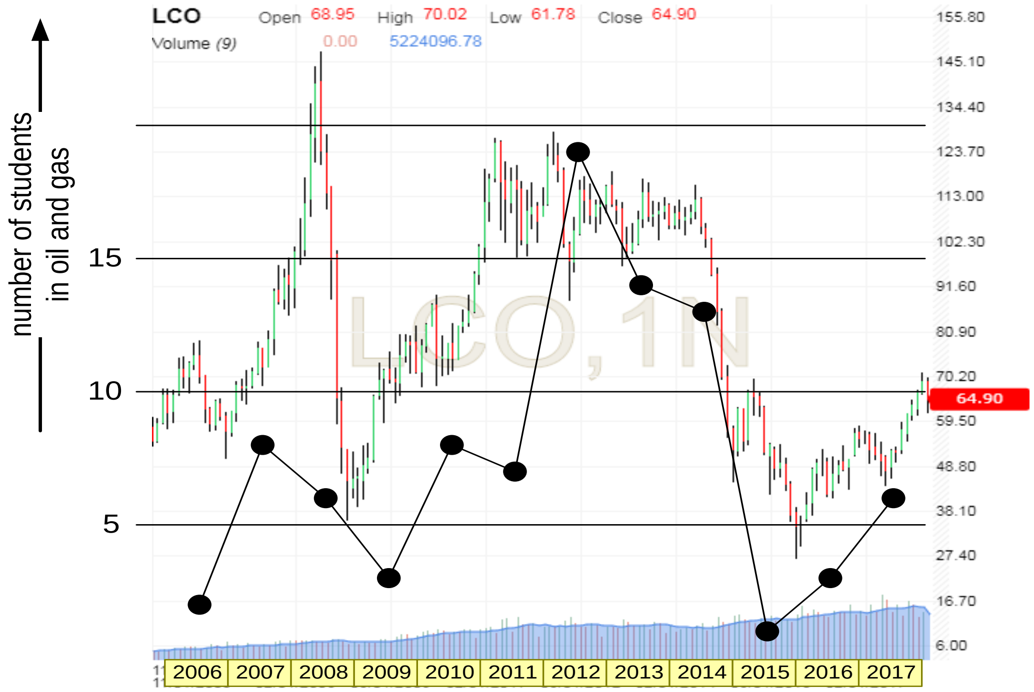

Figure 5: Correlation between Brent oil price and number of students in the Oil and Gas domain

11. IMPACTS

Before 2014, the companies entered into permanent employment of the with 95% of the students that they had hired temporarily during the study. Since the drop in the oil price in 2014, we see that our students find it more difficult to find a fitting job. The Norwegian unemployment rate was just above 3% in the period 2010 to 2014 and increased to just above 4% in the period since 2014, and youth unemployment rate of about 10%. In the cases where some students were laid off at oil and gas companies, the institute was able to find employment elsewhere among the Industry Partners.

Partner companies gradually build up their systems engineering capacity. However, we see quite a difference in the capability of companies to retain the alumni and to use them to develop their systems engineering capability. Especially medium sized companies seem to benefit more from integrating the alumni in their organization since they seem to absorb our alumni more consciously. Larger oil and gas companies downsized so much the last years that it is difficult to assess the impact in this domain. At the same time, we see that the oil and gas domain globally got convinced of the relevance of systems engineering. Major companies like Shell, BP, GE Oil and Gas, and TechnipFMC participate in the INCOSE working group on oil and gas.

12. INVOLVED STAKEHOLDERS AND BENEFICIARIES

Industry and students benefit from the case by obtaining systems engineering competence. The university college benefits from the case, by learning from the educational model. Also, the impact of the program for NCE-SE industry cluster is profound through systems engineering competence building, multi-domain case discussions in the classroom, and cross-industry collaboration projects.

13. AWARDS / RECOGNITION

Has there been any recognition of the case through awards or other third-party recognition of the case study?

The success of the program inspired the university college to expand the industry master model to other studies. The so-called Industry Academy has the ambition to roll out similar educational models for nine more industry master programs within 2022.

The Confederation of Norwegian Enterprise (NHO) refer to the industry master program as the best practice in their presentations of education models in Norway; "Collaboration between working life and academia, both at institutional and study program level, facilitates higher quality and more relevance in education. The industry master program at the University College of South-East Norway is an excellent example of this. It is especially the integration of learning on campus and learning through work that characterizes these types of programs. NHO welcomes more such offers!"

The industry master program has increased the number of industry partners from six in 2006 to 32 in 2018. Feedback from one of the industry partners, TechnipFMC, shows that having students in the industry master program is of great value for the company: "The fact that they get practice and theory intertwined, helping them to relate the knowledge gained from studies of issues that arise at work, which in turn increases a better understanding of what they learn and possibly a faster learning curve. We can help to develop talents while receiving new knowledge that we can take advantage of".

LESSONS LEARNED

14. PRIMARY CHALLENGES

The cultural differences between academics and industry are large. A challenge for academics is to open up and make the step to look from outward in, e.g. from industrial perspective to needed methods and techniques. Challenge for industry is to see the need for structural approaches and long-term investment in competence.

In the academic world, interdisciplinary fields struggle. These fields cross organization boundaries, forming an organizational challenge. The strong industrial orientation translates into a specific educational approach. These aspects make systems engineering in the academic world an odd duck. In our experience, profound industry-academia integration benefit from the work we have done through the years with enhanced syllabi descriptions. Here, the industry assumes our alumni possess sufficient knowledge and focus more on developing skills in using their knowledge base in business. These topics materialize regularly in our formal forums for industry-academia integration.

15. SUCCESS FACTORS

Close cooperation with industry is essential. This requires regular contacts at various levels. The academic staff needs significant industrial experience to make this cooperation work.

Connecting theory and practice is essential for experiential learning. In the program this happens in individual courses by industrial examples and the use of cases from students' practice, in the special course Reflective Practice, and in the final master project.

16. TRANSFERABILITY

The fundamental model of experiential learning, e.g. studying and working concurrently, is applicable in general. This model was quite common decades ago. In some areas, like health care, this model is still normal. The model is relevant for any discipline, where the competence depends more on higher order thinking skills, than knowledge and fundamental skills.

FURTHER INFORMATION

17. PUBLICATIONS / ARTICLES

Gerrit Muller, How to start a new Master Study in Systems Engineering? Proceedings of INCOSE 2012 in Rome

Gerrit Muller. Creating an Academic Systems Engineering Group; Bootstrapping Systems Engineering Research, CSER 2009 in Loughborough

Gerrit Muller, Reflective Practice to Connect Theory and Practice; Working and Studying Concurrently, CSER 2015 in Hoboken, NJ, USA

Merete R. Faanes, Developing Reflective Engineers. PhD thesis NTNU 2014, Trondheim, Norway

18. LINKS

USN Systems Engineering Industry Master

News article in Finansavisen

News article in Scandinavian Oil & Gas Magazine

19. KEYWORDS

Experiential learning, industry cooperation, reflective practice, systems engineering

20. PUBLIC CONTACT DETAILS

USN
NISE
Gerrit Muller
Hasbergs vei 36
NO-3616 Kongsberg
Norway

Phone: +4731008913
E-mail: gerrit.muller@usn.no
Web: USN Systems Engineering Industry Master

University Industry
Innovation Network