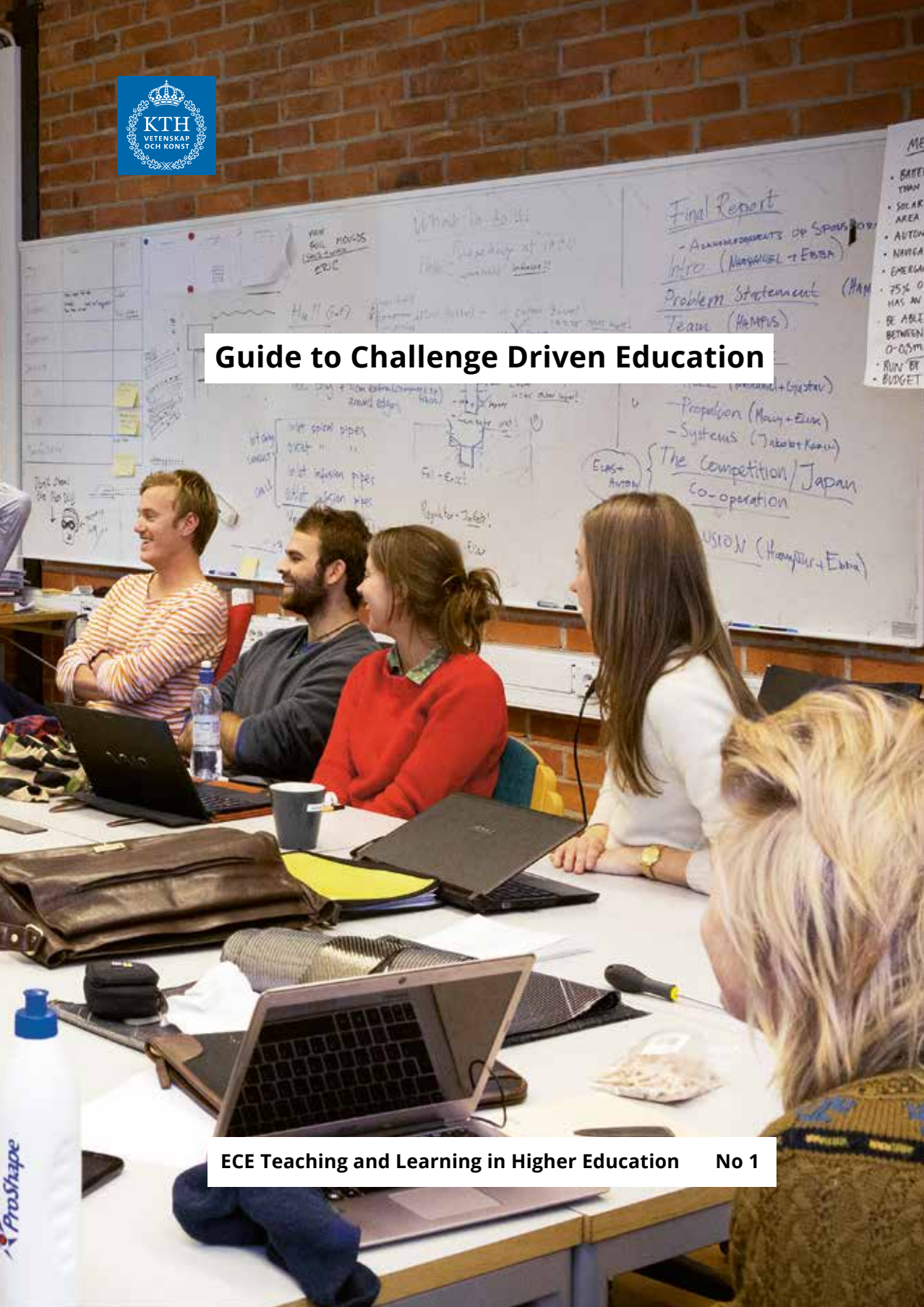

Guide to Challenge Driven Education

ECE Teaching and Learning in Higher Education No 1

Guide to Challenge Driven Education

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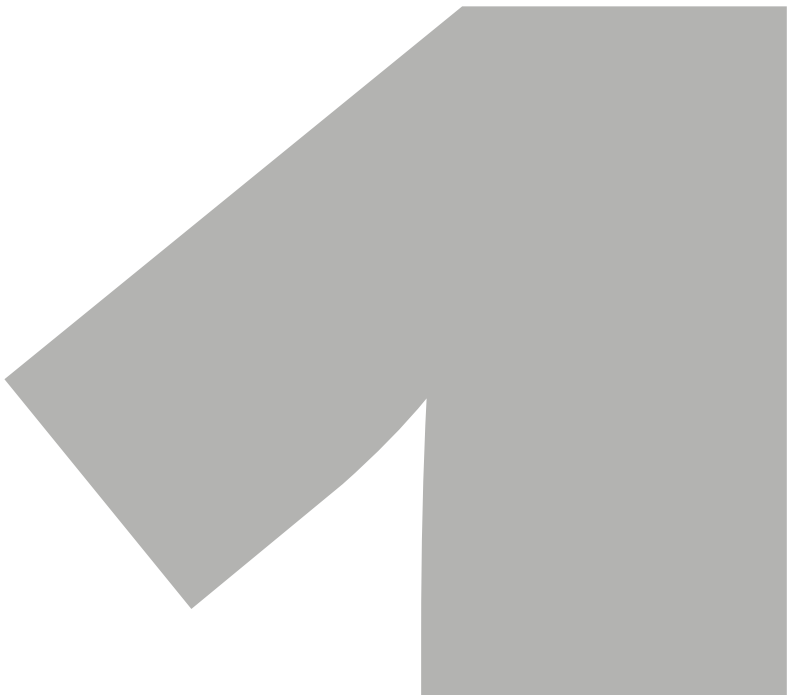
ISBN: 978-91-7595-089-1
Online version: https://www.kth.se/social/group/guide-to-challenge-d/

Table of Contents



1. Introduction

Today our societies face a range of complex challenges, from sustainable development to ageing populations and the well-being of their citizens. University graduates, in particular engineers, can contribute solutions to societal problems that are trans-disciplinary, challenge driven and require skills beyond the knowledge of a single discipline. The role that universities play in societal development, beyond that of new knowledge creation, is gaining increased attention. How do universities address today and tomorrow's societal problems through education? How does society interact with universities and vice versa?

People that enrol in university studies are often driven by a wish to make a difference in society. Universities around the world share a large pool of young, creative, curious students that want to have impact. To unleash the potential of young learners, to provide them with the skills to achieve their goals and support their entrepreneurial mind-set is a constant challenge in university education. Hence, the way we teach and train future generation is of utmost importance for both the individuals at our universities as well as for the development of our societies.

Specialized knowledge will always be at the core of a university graduate's expertise. This Guide advocates that specialised knowledge be complemented by and built through open-ended, challenge based, interdisciplinary team work. Such an approach will enable students to bridge the gap between knowledge and societal demands, enabling them to make a contribution to society. Society cannot waste the talents of young people by leaving them unprepared to enter the workplace smoothly and speedily after graduation. Skills in solving open problems in teams greatly increase a graduate's employability. In addition, we believe that the integration of open-ended, needs-driven problems in university education provides crucial competences for future decision-makers – for both the known and the unknown challenges ahead of us.

This Guide aims to support university teachers and societal collaboration partners through providing advice and inspiration for challenge driven project education. It is our hope that this Guide can serve as a platform for discussions on how to set up and realize good learning projects, leading to excellent training and development of students – as well as delivering relevant proposals for the development of solutions.

Not all universities are familiar with the didactics of challenge driven learning, nor are we all comfortable in grading and assessing individual student performance in project work in teams. Society at large lacks knowledge about the potential of open-ended, team based project work. When the world need young people skilled for new complex challenges, we need to develop methods and processes that will ensure academically correct performance evaluation. Teachers engaging in project driven learning also encounter a new dimension for interaction with society and engaging with student teams requires different competencies compared to standard classroom education. It becomes the responsibility of the teacher to assure that the student groups develop into high-performance teams and to avoid team failures.

The Guide will be delivered in a printed version and in a dynamic web version, this providing an opportunity to collect experiences from colleagues in different environments around the globe. It is our ambition to develop the Guide as a meeting place of universities and their teachers as well as those stakeholders that want to engage with young graduates for the benefit of societal development. This is the first version – we still call it Work in Progress – we welcome your reflections and proposals for improvements!

Stockholm, May 2014

Margareta Norell Bergendahl
vice president strategic collaboration, KTH

Ramon Wyss
vice president international affairs, KTH

1.1 Challenge driven projects in engineering education

A brief review of the history and trends of engineering education throughout the 19th century shows the driving forces that have led to an increase in challenge driven project courses in university curricula. Harwood (1) argues:

> "Over the last few decades engineering education in several countries has been under fire. In France industrialists complained during the 1990s about the lack of practically oriented engineers while in Britain a decade earlier the Finniston Report (and others since) voiced similar discontent. In the USA during the 1990s staff at many engineering colleges debated how best to reform undergraduate engineering education. For some academics the issue was how to bring education closer to industrial needs; for others, foremost among them Eugene Ferguson, there was serious concern at the decline in graduates' design-skills. In each case critics complained that engineering education had drifted away from an earlier practical orientation, becoming increasingly irrelevant to actual needs."

Parallel with the debate on what skills and knowledge the engineers that we are educating should gain and for whom, there has been a growing insight into how and when students learn and gain the most from their university studies. One main distinction in students' learning strategies was shown by Marton & Säljö (2) in the 70s; while some students in certain situations, adapted a surface approach to learning and tried to memorize in order to repeat what they were reading, other students tried to understand the material in order to explain and apply it in new situations by adopting a deep approach to learning. This distinction has now been investigated further and tested in many fields, including engineering education. (3)

Key aspects for encouraging a deep approach to learning are: student perception that deep learning is required, a motivational context, a well-structured knowledge base, learner activity and choices, assessment based on application to new situations, interaction with others and collaboration. (4)

Critiques against traditional engineering education argue that the first years of studies are teacher-centered in order to handle large student groups, that students are provided with papers and books to read too often that the teachers have chosen, and that the assessment tasks show low variation in concepts

and ideas. Traditional approaches tend to emphasize root learning and covering material, while diminishing the value of conceptual understanding, creativity, interaction and independency among the students. (5)

Different initiatives and reforms have been developed to address the two challenges described above : that engineering education isn't really as problem-oriented as it should be, and that educational environments not well enough designed to ensure that students gain the best from them.

One engineering education reform initiative is CDIO (6) (which stands for Conceive, Design, Implement and Operate) founded in 2000 by MIT, the Royal Institute of Technology (KTH), Linköping University and Chalmers University of Technology. Today in 2014 almost 100 higher educational institutions from all over the world are members. The first four CDIO requirements for the reform of engineering education are:

1. The program adopts the principle that product, process, and system development and deployment - conceiving, designing, implementing and operating – are the context for engineering education. Challenge driven team based project courses are thereby a common element, in order for the students to work in a context that looks and works like their future work places.

2. The education emphasizes the technical fundamentals, while strengthening the learning of personal and interpersonal skills; and product, process, and system building skills. The integration of disciplinary knowledge and skill training is thereby a key element of CDIO.

3. The learning outcomes of students in a program should be set in a way that reflects the viewpoints of all key stakeholder groups: students, industry, university faculty, and society.

4. Curriculum and pedagogy are revised to make engineering educa tion more likely to attract, retain, and graduate qualified students into the profession, without compromise to quality or content.

A common answer to the main needs for change in engineering education seems to be students working in team-based challenge driven project courses.

> ”There is a tendency among our students in year one [undergraduate level/first cycle] that they have the feeling that you know what you know. And that learning and the search for knowledge and information is limited to what the course books have to offer. An important part is thereby our early project courses, which early supports students to be confronted with different knowledge gaps, mental models and conceptual understanding. In authentic projects it’s not as easy to refer to phrases or equations you’ve learned. If a beam is to be cut, the students want to feel safe over the fact that they have calculated correctly. The uncertainty that arises in the authentic project works we have is an identification of the interface between knowledge and the need for more knowledge. The ability to improve your competence is strengthened by the fact that you are working in an authentic situation – in order to identify, formulate and solve problems.” (7)

At KTH, a cooperation with Stanford University has also been influential (8). Since the early 1990s, several teachers from KTH have taken part in courses and workshops arranged at Stanford aiming at improving creativity and design thinking in engineering education. These courses and workshops have been the starting point for several challenge based courses at KTH, some of which are described in this guide.

1.2 Using the guide

In the first part of the guide, five examples of challenge driven projects are described in detail, see paragraph 1.3. They were chosen as examples of projects that are contributing to the solution of societal challenges. Additionally, some of them are examples of international cooperation and of trans-disciplinary cooperation. Framing motivating tasks is important in order to create active student commitment. There are also a number of other issues that need to be considered when creating challenge driven engineering education. In our work with teachers experienced in designing and teaching within challenge driven project courses, we have identified further aspects that need careful consideration. We have divided these aspects into three main tensions/challenges described in chapter 2, 3 and 4. In each of the chapters, we also give examples from challenge based courses chosen to illustrate inspiring ways of tackling the main tensions that we focus on. We also offer some suggestions regarding important aspects that you need to consider. We also provide recommendations

on additional reading and links to web sites. In addition, a few learning activities are described and information regarding some concepts is provided.

The main tensions/challenges are:

- **Course Design and Project Tasks**

  What to work on

  In Chapter 2, we discuss and share experiences around setting-up the framework for a project course, on finding relevant and challeng ing project tasks, on the challenge of balancing the need for a "per fect" solutions or products with the need for learning to take place, whilst recognising that mistakes and conflicts shouldn't be avoided. Additionally, different learning activities suitable for integration into a project course will be explored.

- **Setting up and working with teams of students**

  Who to work with and how

  In Chapter 3, we discuss different approaches to setting up teams. Team processes, feedback, and the role of the teacher as supervisor and coach of both students and teams are also discussed.

- **Assessing the project work and solutions**

  What outcome to expect

  Chapter 4 focuses on the assessment of the project work. We discuss aligning intended learning outcomes with assessment tasks and assessment criteria, as well as how to promote active involvement and time on task through assessment tasks. Common assessment forms related to project courses, both formative and summative, are highlighted. We also give some information on IPR issues and finally, we discuss course evaluation as a tool to improve and develop a course.

The different aspects and the variety of options that relate to the tensions/challenges are summarised in table 1.

Parallel to this Guide, there is a web version that also covers additional examples on challenge based courses, programmes, intended learning outcomes, assessment criteria etc, https://www.kth.se/social/group/guide-to-challenge-d/

1.3 Challenge driven projects – five compelling examples

These examples are chosen to inspire you to set up projects that have possibilities to contribute to solutions for societal challenges and problems.

ASPECTS	A VARIETY OF OPTIONS		
PROJECT TYPE	CASE/TASK BASED PROJECT	DISCIPLINARY BASED PROJECT	PROBLEM BASED PROJECT
Task formulated by	External partner	Teacher	Students
Type of teams	Disciplinary/Inter-disciplinary	Disciplinary/Inter-disciplinary & Heterogeneous/Homogeneous	Heterogeneous/Homogeneous
Teams set up by	Students	Students & Teacher	Teacher
Set up of teams based on	Team role or personality test	Knowledge/skills/grades	Gender
Roles in teams divided by	Students	Students & Teacher	Teacher
Teacher's role	Supervisor	Supervisor & Facilitator/Coach	Facilitator/Coach
Lectures decided by	Teacher, in advance	Teacher, during the course	Students, upon demand
Project planning model decided by	Teacher	Teacher & Students	Students
Assessment	Formative & Summative	Summative & Individual level	Group level
Assessment forms	Written	Oral presentation	Prototype
Assessment, written forms	Report & Reflective journal or portfolio	Poster & Reflective journal or portfolio	Log book, individual or group
Feedback from	Teacher	Students	External partners
Course evaluation	Evaluation form	Evaluation meeting	None

Table 1: Aspects and possible options related to the tensions/challenges in project courses.

The five examples are:

- Solar-powered energy-efficient router enables broadband in rural Tanzania
- Bridging communication gaps between different care providers
- Unmanned, solar-powered boats win Japanese challenge
- Dry toilets – the basis of a sanitation enterprise in Dar es Salaam
- A market-modified flood pump for a changing world

1.3.1 Solar-powered energy-efficient router enables broadband in rural Tanzania

Installation of solar-powered router in Tanzania.

Starting in 2005, fifteen student teams, with an average of six students per team, have worked on a series of consecutive projects to develop the Serengeti Broadband Network. The students have been part of the development of the broadband network itself and of the services the network provides. The network is now in operation, but there are still several challenges to solve, including operational aspects, local ownership and leadership, and utilizing the full potential of the network.

Students have participated in the projects as part of their Master's degrees and have been part of the development work for six months at a time. They have worked under the supervision of a Doctoral student, who has run the projects as part of the Doctoral research. Under the supervision of the Doctoral student, the Master's degree students have been the muscle that has delivered the pro-

ject. Working on the projects has developed the students to a remarkable degree. They often report that course was the one where they really learned something of value, for example that it pays to work together and how to put this into practice.

The students have designed Serengeti Broadband Network itself and have developed a router so that the network can function in the difficult conditions in which it is located, for example in the heat and with an unreliable electricity supply. To achieve this they based the router on one that functions in a high performance context exchangin some components to reduce the energy requirements of the router. They have also adapted the router so that it is not reliant on electricity grid supply but can instead run on solar power.

The students also had to develop a new battery technology, as traditional lead batteries become too warm in the heat and there are no resources to top up the batteries with water. They have set out the routers and tested that they work. The new battery is capacitor-based and uses what is known as ultra-capacitors as cells, where every capacitor holds a charge of 3,000 Farads. This is many orders of magnitude greater than traditional capacitors.

The broadband currently links the two district capital cities of Mugumu in the Serengeti and Bunda in the Bunda district. The fiber is also accessible in the rural Nata village, a settlement of around a hundred homes. The village has a secondary school and a health centre. These are so far the primary pioneering customers for the network in these rural areas.

The broadband network has a large capacity so it can provide for local services, for example in healthcare and education. The network is located in one of the poorest areas of Tanzania, where agriculture is in great need of support. The broadband network can also disseminate information, for example by providing access to weather forecasts. It is free to make telephone calls within the broadband network and there are local social Facebook-like network services, which have become popular discussion forums.

The need for broadband services in the area covered by the network is similar to the need worldwide. The local authorities can use local websites to disseminate information and there is also a health portal being developed in cooperation with Stockholm's Karolinska Institute and University Hospital. There is a huge potential for further development. To date only a small fraction of the local capacity of the network is being utilized.

1.3.2 Bridging communication gaps between different care providers

Under the title of 'The City is our Laboratory' students from a range of subject areas have run a project to tackle current societal problems and the challenges faced by public agencies. One project developed a Care Diagram (Vårdagram) tool to make communication easier between elderly people with multiple health problems, home care providers and primary care services.

The project course is called OpenLab and is run as a joint collaboration involving Södertörn University, KTH, Stockholm University and Karolinska Institutet. The course works together with the County Council of Stockholm, the City of Stockholm and the Swedish Counties Agency. These public bodies provide the problems for the students to solve selected from amongst the challenges that the public agencies tackle on a daily basis.

A significant challenge faced by the County Council is the care of elderly people with multiple health problems. This group of people is often in contact with several different care providers, who provide care independently of each other. It is difficult for each of the care providers to access and use information from the other care providers, which results in an increased risk that important early medical signals are missed. The County Council asked the students to address this challenge.

The students in turn are given great freedom to consider how to tackle the challenges, which differentiates the project from more conventional consultancy practices. It is intended that the agencies commissioning the project work will gain new ideas and, over the duration of the course, the ideas proposed can both surprise and shock. This more creative approach gives the agenc- ies a possibility to consider new approaches and new ways to tackle current social urban problems.

Approximately halfway into the term, students at the OpenLab present a half-time concept delivery to the County Council illustrating a range of initial ideas. Through a dialogue with the agencies commissioning the work, it was decided to carry one of the concepts further and develop a prototype for a communication tool, the Vårdagram Care Diagram. But how is the Vårdagram Care Diagram useful?

The Vårdagram is a web-based form that patients with multiple health problems can complete on their own or together with their home care assistants. The

Vårdagram is able to show if a person needs primary care in a way that is more efficient than if the home care assistants or the patients themselves have to decide if contact with primary care services is necessary. The care diagram has the function of bridging the gap between two gigantic organisations, home care services and primary care services, by sharing the information that the organisations need in an efficient way so that the best possible care can be provided.

The students also proposed a new professional position within home care services; a care coordinator. The care coordinator would be responsible for entering the information in the Vårdagram care form, together with the elderly patient. This is a role that does not currently exist, but one that could be developed within home care services.

In the remaining half of the project the students completed a prototype of the Vårdagram care diagram. They also analysed the opportunities and obstacles for the development of the final product, including taking existing legal requirements and other regulations into account.

After the project the student group was given the opportunity to work further with the commercialisation of the communication tool. One student will also work further with developing the content of the Vårdagram care diagram as part of a Master's degree. The content must be refined to make the tool usable with regard to which indications are important for primary care to be able to prioritize interventions, and also with regard to content format so that the tool can be efficiently used by the home care services, elderly patients and their relatives.

1.3.3 Unmanned, solar-powered boats win Japanese challenge

The Naval Design course at KTH challenges its students to develop a solar-powered boat for a competition in Japan. The project is both a technological and cultural challenge during which the students work together with Japanese students to put their designs into practice. In 2013 the students exceeded all expectations by finishing in first and second place in the competition – and in 2014 a new group of students is aiming to emulate this success.

The competition is won by the boat that completes a twenty kilometre course on Lake Biwa in Japan in the shortest time. The boat must be able to pilot itself during the competition – the students are not allowed to give the craft any commands during its voyage. The craft must also be able to complete the course

Students working on developing the solar powered boat

using no other source of energy than the sun and a limited supply of batteries. The Swedish students worked intensively over four months to develop the design to complete the first part of the course. They divided into three groups, each group working in parallel with different aspects of the project. One group worked on the hull, one group worked on propulsion and one group worked on the control system. In addition they collectively shared the responsibility for communicating with the Japanese students and for finding a sponsor to finance their journey to Japan in August.

When the Swedish students arrived in Japan they built the new boat – a catamaran – together with their Japanese project counterparts. They also worked together to build a boat of a type that had already taken part in the competition in 2012. The cultural differences were obvious, but the trip would be a memory to last a lifetime. The students stayed in a typical Japanese ryokan, slept on tatami mats and ate rice, fish and miso soup for breakfast.

When the competition began it soon became apparent that the boats were up to the job. They claimed the first two places. The experiences of the Swedish students form an important lesson for the following year's students to learn from, as the course will take part in the competition again.

Through harvesting the experiences of students from the previous year, the collaboration with the Japanese university becomes more efficient. This year's project has been initiated earlier, which is an advantage. Other advantages are that the project will be able to test the boats at a University of Tokyo testing facility and it is also planned that the students will have more time in Japan to prepare for the competition.

In addition the new project group is planning a partially new technological solution. The new boat will 'fly' on wing-like supports that will lift the new single-hull out of the water – with the intention of reducing the friction between the boat and the water, and consequently reducing energy consumption. A new automatic control system will maintain the hull at certain height from the surface of the water. The students will also design a new propulsion system, using new solar panels and propellers.

It is creativity that takes the driving seat during the project. The only certainties are the prerequisites: the rules of the competition, how large the solar panels can be and so on. The solutions are limited only by the imagination of the students, their level of commitment and their ability to work together.

Additional information: http://kthsolarboat.se/index.php

1.3.4 Dry toilets – the basis of a sanitation enterprise in Dar es Salaam

An easily constructible dry toilet, developed by students at Aalto University, Finland, proved a robust basis for better sanitation and a business enterprise in Keko Machungwa, a poor settlement in the city of Dar es Salaam, Tanzania.

A group working on a sanitation project in Keko Machungwa together with Aalto.

The business opportunities developed included the construction of toilets, sale of fertiliser and farming of organic vegetables.

At the start of the project the students meet with a group of several women and a few men who were already working on a sanitation project in Keko Machungwa. This group was supported by the Centre for Community Initiative in Tanzania, a non-profit organisation aiming to improve quality of life in informal settlements and rural settings by supporting micro finance community-driven development activities.

The students involved had different specialities; environmental engineering, design, architecture and business. As the group had no prior experience of sanitation, the first step in the project was to collect background information ahead of going to Tanzania to meet with the community in Keko Machungwa. Once there they worked together with the community group to find solutions, coming up with a theme for a dry toilet as the basis for a sanitation business.

The students decided to design a prototype dry toilet with capabilities for water harvesting, composting and urine separation. Dry toilets are hygienically far

superior to the existing solutions in the settlement, and they can also be used to produce fertilizer. The prototype developed by the students had to be of excellent quality, so that the community project could actually make a profit by using the toilets, e.g. by selling fertilizer.

One important aspect of the design was that the project members from the community had to be able to produce the new toilets themselves and develop the business. Dry toilets had been tried before but they were not used and were considered too expensive. As a result of the project, women and men in the community now act as dry toilet technicians and also have developed their knowledge of rural sanitation requirements. This local group will work to expand the business, making more toilets and educating the rest of the inhabitants of the settlement in sanitation and hygiene. Some of the students will also be part of this development, as the Finnish Government has granted funds to realize this dry toilet business in Keko Machungwa.

The model of the dry toilet developed by the students is not only cheap and easy to produce; it is also an improvement on earlier models. For instance, the toilets are able to harvest rain, which also makes them cheaper as it is not necessary to provide water for hand washing. The project has now developed plans for how to use the dry toilets at public schools. The toilets should be placed around a garden area where the compost produced can be used directly, and the harvested rainwater can be fed to the hand washing areas in the school.

Additional information: http://www.aalto.fi/en/current/news/2013-07-03-002/

1.3.5 A market-modified flood pump for a changing world

Due to ongoing changes in climate, the risk for flooding has increased dramatically around the world – leading to a challenge defined by a pump company. The globally-operating Swedish pump company, formerly known as ITT Flygt and now called Xylem Water Solutions, wanted to increase its product portfolio by adding a competitive flood pump solution, and contacted KTH. A large group of students from KTH developed a submersible flood pump together with the company. The group also helped the company to analyse the market for flood pumps, so that the prototype could be designed to suit future customer needs. For more than six months 16 students worked together with four of the company's employees to investigate market opportunities and design a prototype for a pump.

Flood pump (120 litres/s) developed by students, Integrated Product Development.

Prior to the start of the project the company was already a world-leader in submersible pumps. But the company didn't have a pump optimised for flood situations in its product catalogue and knew too little about the requirements of potential customers; what would the customer want and how would the customer gain access to the pumps? Flood pumps are special in that they do not need to pump water over a considerable height. In many instances it is sufficient to pump over a height difference of around half a metre.

The pumps must also be able to be moved into place very quickly when they are needed. Therefore they must be available already before the flooding occurs, perhaps placed in a store cupboard or shed. They must also be sufficiently small to be able to be carried to and lowered into a drain. Finally the pump must have the capacity to pump very dirty water at high speed without breaking down.

The students were divided into two groups, with one group responsible for market analysis and one group responsible for design. The market analysis group interviewed different stakeholders to investigate who would be the potential customer, for example insurance companies, municipalities, government agencies, emergency services and companies offering complete pumping solutions. The students concluded that the pump has a global market. This is due in part to an increase in flooding worldwide. The market analysis group put forward three proposals for how Flygt could reach the global market. One option is to

sell pumps and another option is to lease pumps. The final option is to offer the pumps, pump operating personnel and maintenance as a complete “package solution”.

The design group constructed the flood pump, together with employees of ITT Flygt. The design was based on performance requirements, easy of handling and reliability. The pump needed to have the capacity to be able to pump at a speed of around 100 litres per second. It also had to be easy to take apart and put together, and had to weigh less than 50 kg. These are stringent requirements to fulfil but the students succeeded in the end - and by a good margin.

As part of the project presentation the students demonstrated the pump by using it to empty a 1500 litre tank that was filled with water. The 36 kg pump prototype emptied the tank with a spectacular flow at a maximum speed of 120 litres per second – mission accomplished!

Notes:

Notes:

2. Course Design and Project Tasks

In this chapter we discuss the issues to be considered when designing a project course, such as choosing project tasks, formulating the intended learning outcomes and integrating different kinds of learning activities.

2.1 Start with a wider perspective

As with the design of any course, one should always consider what purpose, aims and intended outcomes the project course should be designed for. Aspects such as students' possible future project work and the variety of useful teamwork skills in their professional working life should be analysed. There have been major surveys carried out regarding this matter in engineering education; see for instance the CDIO Syllabus v 2.0. (9)

The course you are designing might be one of the building blocks in a complete study programme, where collaboration with teachers over the study years is a crucial part. By doing so, the design of project courses and other types of study courses over the study years can be linked to each other, creating a progression of important knowledge, skills and competencies, and offer a variation on what is practiced and assessed.

An Example of progression in a study programme:

The progression of project work skills in the Degree Program in Design and Product Realisation has been carefully designed. It's important that the students have practiced the complete cycle of product realisation in their first project course, in year one. Some parts of the process can be a bit messy, and the key is to keep the project tasks in the first year quite simple or easy to relate to. Designing a home for compact living is an example of project tasks chosen. Also, guidance and feedback from teachers should be frequent.

With knowledge and experience of all steps in the process of product realisation, the students are more prepared in the following project courses to deal with more complex industrial design tasks. Knowledge from Solid Mechanics, Mathematics, Mechanics, Electrical Engineering and Component courses must be applied. The tasks are much more user-centred, with an actual client ordering a solution, which demands real solutions and delivery on time. Also, since the solution should be presented to the clients by the students, abilities to make judgments and communicate clearly are practiced and assessed. Two intended

learning outcomes (ILOs) are: a) 'Students should be able to describe and justify solutions and design for a certain target group' and b) 'Students should be able to, in sketch and model, visualise and present ideas and products'.

Information retrieval, on for instance users' and customers' needs, other demands that can be made on the product, existing solutions and provided technology is an important skill that is more and more emphasized over the years, as well as time management, while the teachers step back more and more.

An Example of progression in a study programme:

In the Degree Program in Electrical Engineering, the progression of the students' project working skills over the study years also has the overarching aim of giving the students experience within the complete process early on, and helping them see the importance of taking careful consideration of all steps in the process. The skill of creating and maintaining a well-functioning project plan is emphasised in year one, by close guidance and conversations with the teachers. A student manual called Handbook for smaller projects (10) has been written by the teachers in order to ensure that the project processes are carried out well.

The demands on the students' project plans increase over the study years, and in year three project outcomes that can be evaluated must be defined. Here, the students are working with the Work Breakdown Structure (WBS) method (11). As with the example from Design and Product Realisation, the complexity level of the project tasks increases over the students' study years. In the larger project work in year three (15 ECTS), the tasks are formulated by the Master's Programs in Electrical Engineering. For instance, in one of the course rounds, the main theme was Communication Systems for Rescue Service, where one project could be to design ad hoc networks for the positioning of fire men in a building.

The demands on the students' presentations of their work also increase over the study years, where public conferences and scientific papers are used in year three as assessment tasks in the larger project course. The size of the student groups decreases from five in year one, to four in year two and two students per group in year three.

Suggestion: If the course you are designing is part of a degree program, it is necessary to make sure the different courses are linked to each other, that a progression of important knowledge, skills and competencies is created, and that a variation on what is practiced and assessed is offered.

2.2 Choose and formulate project tasks

As described by Kolmos et al (12), there are three different types of projects in educational settings. In the first type, the case/task based project, the discipline and the problems as well as the methods are decided in advance. The teachers/supervisors in a case/task based project plan and control the projects. The second type, the discipline based project, means that students have the opportunity to choose/define the problem while the discipline and the methods are decided in advance. The teacher/supervisor manages the learning process. The third type, the problem based project, differs from the other two in that the problem is the point of departure and the problem will guide the students to appropriate disciplines and methods. In problem based projects, the students have to take responsibility for their own learning and the teacher/supervisor has a less active role.

The courses exemplified in this guide are inspired from all of these different approaches, since some have more open tasks while others have pre-defined tasks for the students. In some cases the tasks come from external partners, even then they can be both open-ended as well as more well-defined. There is also a balance between having a focus on the product on the one hand, and/or focusing on the learning on the other hand. Prince and Felder (13) conclude that ”A trade-off exists between instructors being fairly directive in choosing projects, which helps maintain a focus on course and curriculum objectives, and allowing students the autonomy to choose their own project formulations and strategies, which increases their motivation”

An Example from Communication System Design illustrating well-defined project tasks from external partners:

In this course, project tasks are formulated by external clients, e.g. Karolinska Institutet (KI), Dar es Salaam Institute of Technology (DIT) and Tanzania Commission of Science and Technology (Costech). The assignments cover challenges as “Community Health Portal – a community health portal is to be established with entries for health workers, patients, selected relatives of patients and the general public. The purpose is to provide e.g. health and drug information, guide-

lines, decision and drug management support" and "Extension of the Serengeti Broadband Network – the main technical challenge is power supply, the solution has to be as power-lean as possible and has to use solar power and innovative energy storage".

In this course, the students get rather well-defined assignments including the aim to construct products/devices/computer simulations. This course is more in line with the case/task based approach, even though it contains elements of the problem based approach, e.g. students having to identify their own learning needs (13, 14)

An Example from the course OpenLab illustrating open-ended problems from external partners:

The City of Stockholm, Stockholm County Council and Stockholm County Administrative Board provide students with open-ended challenges, and the stakeholders do not expect a product in the end, rather proposals for solutions to complex social issues. Examples of challenges to be investigated are "Traffic and congestion - One of the single most significant challenges is increasing access to the transport system while minimizing the climate impact of the traffic sector" and "An ageing population - By 2015 more than 20 percent of the EU's population will be above the age of 65. The number of people over 80 in particular is growing rapidly. Older people have special healthcare needs and the system needs to be adapted to be able to provide adequate care while being economically sustainable".

In this course, the students have to specify the problem formulation and methods by themselves. Thus, this course has similarities with the problem based project approach. (12)

Suggestion: There is a variation in the courses described regarding whether they have ill-defined and open ended real-world problems or clearly defined assignments for the students to work on and whether the projects are formulated by teachers or by external partners or industry. Prior to deciding upon the challenge/project task, start with the intended learning outcomes of the course as described in the next paragraph and decide how to balance between focusing on the level of the result of the project work and the level of the learning. If you have external contacts that can provide you with challenging project tasks,

Students working on solving the problem with traffic and congestion, OpenLab.

use the intended learning outcomes as a backdrop when you decide upon the exact formulation of the tasks. If you, in your course, have an intended learning outcome similar to “Handle technical problems which are incompletely stated and subject to multiple constraints”, the challenge should be formulated in a manner that opens for the students to decide for themselves how to approach the problem.

2.3 Frame the Intended Learning Outcomes

Whether you are designing one or several project courses that will need to provide a progression of project working skills, or only designing a single project course that stands on its own, it is important and useful to define the intended learning outcomes (ILOs) of the project course. What knowledge should the students be able to apply? Which team work skills will be assessed? How should they be able to communicate and visualise their results and solutions? The following section will take a closer look at the choices to be made in the formulation of the intended learning outcomes in a project course.

Many of the aspects covered in the guide will relate to the intended learning outcomes (ILOs) of the project course. The ILOs are statements on what the students will be able to do as a result of the course: what type of knowledge, skills and abilities will be gained, in which contexts, and on what conceptual level. Typically, in a project course, ILOs are re-formulated and new ones added, as part of the continuous course improvement over the years, since many different learning opportunities are discovered when the course is running.

A well designed project course will align the activities and assessment tasks with the ILOs, so that students can practice and show his/her learning progress, and so that teachers can make sure the ILOs are reached.

The main critical aspect when defining the ILOs and starting the design of your project course is finding the balance between focusing on the level of the result of the project work (the solutions, the ideas presented, the products and so on) on the one hand, and the level of the learning and development of the students themselves and their possibilities to explore new ways of thinking, on the other hand. This should be taken into consideration when designing and revising your course.

The following criteria, as shown in table 2, can be useful when writing the ILOs for your project course with a focus on students’ learning and achievements.

ILOS SHOULD	NOT AN ILO
State the intended learning - Tell what the student should be able to do as a result of the course	”Foundations of structural mechanics, analysis of thin-walled stiffened shells, plates, stability theory and introduction to finite element methods. The course will give the student a basic knowledge of the structural behaviour of beams, plates and shells, and of the analysis and design of these types of structures, specifically, strength, stiffness, and weight issues for unstiffened and stiffened thin-walled structures.”
Be in terms of observable performances - clear and specific enough for assessment to be based upon them and so that the students themselves would know if they have reached them	“… To have an understanding of XYZ” “… To be familiar with XYZ”
Be hinting at the level of understanding - see more about levels further down!	“The students should be able to describe the properties of materials”

Table 2. Criteria for writing the intended learning outcomes, ILOs.

AN ILO

After the course you will be able to

- identify and describe the purpose and function of different structural members in lightweight structures.

- choose appropriate structural elements for a given problem, with respect to function and weight.

- design thin-walled beams and stiffened shells with respect to stress levels, deformation and structural stability.

- describe the conacepts of finite element software tools and apply them in analysis of standard structural members.

- explain discrepancies between results from different analytical methods through knowledge about the various approximations they are based on

- describe and compare the XYZ concepts

The student should be able to

- explain the properties of materials in relation to chemical binding

- choose the appropriate materials for a given construction with regard to function, conditions of operation, economic and environmental factors

	FREQUENTLY USED VERBS FOR THE ILO
LEVEL 1	Calculate, Execute Relate, Show Solve, Use Describe, Develop Formulate, Test, Compare, Interpret
LEVEL 2	Organize, Sketch Prepare, Plan Model, simulate Produce, Categorize Compile, Explain Discuss, Relate Summarize Identify and formulate solution paths.
LEVEL 3	Predict, Create, Argue, Combine, Design, Construct, Produce, Evaluate, Prove, Discover, Modify, Reconstruct

Table 3. Three levels of skills and abilities in ILOs

The formulation of the ILOs, with proper verbs and contexts, are always best handled by teachers within the specific field. If you find it useful, beside, in table 3, we have tried to distinguish three levels of skills and abilities with verbs from Bloom's taxonomy (15), based on our experience with how project courses normally are designed. Level 3 is the highest. At the same time, as described in the previous section on the progression of project work skills, a first level project course can, and often should, involve all crucial steps involved in a project work, while the complexity of the project tasks could evolve over the study years.

ABOUT THE LEVEL

Training the students' basic abilities to work in projects, such as:

- Planning and time management.
- Laboratory tools and equipment.
- Searching and collecting information.

Also, creating an overview of the problem solution process.

Frequent supervision and/or lectures.

Project work skills are used in more advanced projects. Knowledge must be applied from other science and engineering courses, which will help students to develop more conceptual understanding and insights. Project papers or essays will promote this even better.

Aspects such as users' needs, ethics, environment and society more common. Target groups and users' needs and knowledge will need to be taken into account during project work, and during presentations and demonstrations.

Critical thinking and independency more emphasized.

Team work skills more emphasized, different teams, often chosen by the teachers.

Critical, independent and creative on the complete project working process. Applications and conclusions on scientific ground.
Very limited amount of information to the students from the teacher.
International contexts.
Mixed working groups.
Strict time frames.
Development and progression can be followed, by for instance portfolios.
Conference format on presentations, with posters and papers.

Example from Lightweight Design/Naval Design describing ILOs on a high and universal level:

In this master level project course, the ILOs are framed so that they state what the students are expected to be able to do after the course, and not on what they are solving within the particular course:

- Analyse technical problems in a systems view
- Handle technical problems which are incompletely stated and subject to multiple constraints
- Develop strategies for systematic choice and use of available engineering methods and tools
- Make estimations and appreciate their value and limitations
- Make decisions based on acquired knowledge
- Pursue own ideas and realize them practically
- Assess quality of own work and work by others
- Work in a true project setting that effectively utilizes available resources
- Explain mechanisms behind progress and difficulties in such a setting
- Communicate engineering – orally, in writing and graphically

The ILOs are on a high and universal level, and they do not state that the students are going to build something as part of the project course. This means that even though every course round has a new and different challenge, the ILOs are the same.

Suggestion: It's important that you frame the ILOs for your course, and re-frame them when you see that this is needed. ILOs should be formulated in the sense that you can always point to them when discussing with students, external partners, teaching assistants and other teachers.

2.4 Integrated learning activities

If your project course will involve ILOs related to team work skills, or creativity, or knowledge about project management systems, then the learning activities and assessment tasks should also focus on this. Below, we describe some learning activities focusing on the creative process and project planning models. We also discuss how to organize lectures in the course. For more information on how to address team work skills, see Chapter 3.

2.4.1 Learning to be creative

One of the groups pitching their solution, OpenLab. Photo: Marie Magnell

When working on finding solutions to different kinds of challenges, the students will need to use their creativity. As stated by Robinson (16), creativity is something we need to learn:

> "It is often said that education and training are the keys to the future. They are, but a key can be turned in two directions. Turn it one way and you lock resources away, even from those they belong to. Turn it the other way and you release resources and give people back to themselves. To realize our true creative potential—in our organizations, in our schools and in our communities—we need to think differently about ourselves and to act differently towards each other. We must learn to be creative."

There are a number of different exercises designed to improve creativity, also known as Idea Generating Methods (IG), and examples are Brainstorming, Collective Notebook, Fishbone Technique, Metaphorical Thinking (17). Below, two methods are described in detail, the Rapid Prototype Exercise and an exercise inspired by Systems Engineering including Brainstorming.

An Example from OpenLab of a learning activity on creativity:

The students in the course are introduced to the creative design process through an exercise called Rapid Prototyping. The exercise contains three steps and it is repeated to allow for all teams' problems to be discussed and processed. The steps include:

1. The first team gives a very brief introduction to their problem/task, i.e. the task that the team is going to work on during the course (e.g. health care needs of older people).
2. All the teams then spend about five minutes to elaborate on a solution to the problem/task just presented. Each team presents one idea/solution, preferably not in text but by using other kinds of materials, e.g. paper, sticky tape, fabric, wire.
3. After five minutes, all groups reassemble and then present, pitch, their "quick and dirty" prototype in maximum three minutes per team.

After the first pitch, the groups move on to the next teams' problem/task and the process starts from scratch again. In total, with three student teams, and thereby three process iterations, about an hour was spent on the creativity process exercise.

For additional information on design thinking, see Stanford methods to improve design thinking practice: http://dschool.stanford.edu/use-our-methods/

An Example of a learning activity on creativity from Naval design/Lightweight design:

The students in previous course rounds used to have problems with the creative phase of the project. For the last few years , systems engineering have offred lectures and exercises in in an antecedent course. This is repeated and extended during the first four weeks of this course. This part of the course is called "First steps in your design process" and contains:

Week 1: The students have to formulate catchy mission statements and descriptions of needs and opportunities, stakeholders' expectations, and a system concept. They will also produce associative and inspirational pictures and ideas for their projects based on brainstorming (see below).

Week 2: The students need to present measurable requirements and a functional architecture.

Week 3: In this stage, they present physical architectures for several design solutions.

Week 4: A final presentation of the work is made.

The change has been successful and the students are now more prepared e.g. to make sketches for the project and identified requirements and stakeholders.

The basics of brainstorming:

- start individually and let the students think for themselves for a few minutes.
- go for quantity, try to get 100 ideas!
- encourage wild ideas; there are no right or wrong ideas.
- don't critique or debate ideas.
- try to build on each idea, try to push or introduce small variation.
- be visual, include sketches, mind maps and diagrams.
- don't go on for more than 45 min.

Brainstorming preparations:

- start with a well-defined statement of the problem.
- cover virtually every wall and flat surface with paper before the session.
- choose a facilitator who should focus on writing everything down and not ideate.

For additional ideas on brainstorming: www.me.umn.edu/courses/me2011/handouts/brainstorm.pdf

Suggestion: To ensure that students develop creative skills, introduce some kind of learning activity on creativity, preferably repeatedly rather than just on one occasion to make sure the students can make use of the method in their project work.

2.4.2 Project planning models

A project planning model usually contains a number of stages/steps which a project has to go through to be successful. There are several project planning models on the market that can be used in educational settings. In some of the courses described in this guide, the students decide upon their own working process in terms of project planning and management. In other courses, there is a project model integrated into the course and the students are working according to that model during the project. In some courses, agile methods such as Scrum and Kanban are taught and used.

An Example of learning activities on a project planning model from First Year Project Course in Electrical Engineering:

In this course, project planning and management skills are important. ILOs state that participants should be able to describe and use the principles of project work, present technical information in oral and written form, and create the fundamental documents required for planning, following up, and finishing a project.

The course contains three parts:

1. Basic project planning, project management and the project model.
2. Execution of the projects.
3. Project evaluation and feedback.

During the first part, there are lectures on how to work according to the specific project management model. In part two , the projects must be executed according to the model. In part three, the students reflect on and evaluate to what extent their project planning was successful.

A project model, which is the structure used in a project, shows the general stages of a project. This particular model contains the following steps: (1) Pre-Study, Start of the project including project plan, (2) Execution of the project including status reports, and (3) Closing the project including final report. There are also other essential aspects of a project which the students need to be aware of, e.g. resources, roles, stakeholders and the so-called “core three”; time, cost and function. The model is described in the course book Handbook for Small Projects (10).

An Example of Agile Methods used in the Degree Programme in Information and Communication Technology:

Students are learning agile methods, mainly Scrum and Kanban,

throughout the study programme. Current problems within software engineering and how they have been addressed with agile methods are discussed to introduce the students to the way of thinking within the agile methodology. The agile development cycle and various modern practices such as for instance, iterative development, pair programming, refactoring, test-first programming, release planning and the combinations of these methods are interwoven in both theoretical and practical courses over the study years.

Scrum: “Scrum is an agile way to manage a project, usually in software development. Agile software development with Scrum is often perceived as a methodology; but rather than viewing Scrum as methodology, think of it as a framework for managing a process. In the agile Scrum world, instead of providing complete, detailed descriptions of how everything is to be done on a project, much of it is left up to the Scrum software development team. This is because the team will know best how to solve the problem they are presented with.” (18)

“Scrum relies on a self-organizing, cross-functional team. The scrum team is self-organizing in that there is no overall team leader who decides which person will do which task or how a problem will be solved. Those are issues that are decided by the team as a whole. And in Scrum, a team is cross functional, meaning everyone is needed to take a feature from idea to implementation. Within agile development, Scrum teams are supported by two specific roles. The first is a Scrum Master, who can be thought of as a coach for the team, helping team members use the Scrum process to perform at the highest level. The product owner (PO) is the other role, and in Scrum software development the PO represents the business, customers or users, and guides the team toward building the right product.” (18)

Kanban: “Kanban is a lean approach to agile software development. Actually, Kanban means many things. Literally, Kanban is a Japanese word that means “visual card”. The core of Kanban means: Visualize the workflow: Split the work into pieces, write each item on a card and put on the wall. Use named columns to illustrate where each item is in the workflow. Limit Work In Progress (WIP) – assign explicit limits to how many items may be in progress at each workflow state. Measure the lead time (average time to complete one item, sometimes called

> "cycle time"), optimize the process to make lead time as small and predictable as possible." (19)
>
> *For additional information on Scrum and Kanban, see www.infoq.com/minibooks/scrum-xp-from-the-trenches and www.infoq.com/minibooks/kanban-scrum-minibook*
>
> Suggestion: If the intended learning outcomes at program level contain project working/planning skills, a course focusing on methodological steps could be fruitful since the students will most likely not learn these skills by themselves. Later on during the program, to secure a progression of these skills, the complexity level of both the project tasks as well as of the students' project working/planning skills should increase. When choosing a project planning model, consider which models are used in industry within the specific discipline and introduce these models to the students.

2.4.3 Peer Learning and Peer Feedback

Students also learn from each other, a concept known as peer learning. Boud, Cohen and Sampson (20) define peer learning as a learning activity that is reciprocal and they state that "Peer learning should be mutually beneficial and involve the sharing of knowledge, ideas and experience between the participants". They explicate the strengths of the method:

> "Students learn a great deal by explaining their ideas to others and by participating in activities in which they can learn from their peers. They develop skills in organizing and planning learning activities, working collaboratively with others, giving and receiving feedback and evaluating their own learning."

Peer learning can be informal and take place within the project teams, especially if the teams are mixed with students from different educational backgrounds. Peer learning can also be formal and more strictly planned and take place during lectures when students present different topics to each other. The fundamental idea with applying peer learning in a course setting, whether students are giving each other feedback, holding lectures, marking each other's work or something similar, is the learning which is gained by "acting as the teacher". By preparing a lecture, reading a team report, listening to a presentation and reflecting over critical aspects to raise, students can become much more aware

Midterm workshop. Photo: Marie Magnell

of the contents, over different ways to communicate, over how important it is to be clear and precise when the teacher will do the marking and so on.

So, when students sometimes are disappointed with not having feedback or lectures only by the teacher, it can be very important to help them see that the

main idea is for them to learn from the lectures and feedback that they give. The teacher's or the supervisor's role will be to provide feedback to the students who are acting as "teachers".

An Example of Peer Learning from Integrated Product Development:

We offer lectures on a number of topics and, adjacent to some of the lectures, the teams are obliged to present aspects of their work to other students. For example, when organising a project is the subject, the teams read a book each on project organisation and then present the content to the other students. Sometimes we use peer learning instead of having lectures on a topic, e.g. the students present different creative methods to each other.

An Example on Peer Feedback from Communication Systems Design:

Halfway through the course, a peer feedback/peer review process is included in which the students give each other feedback on projects. The aim is to improve their work in the project, both in terms of process and product. The groups present their projects for about 20 minutes and then another group provides detailed feedback for about 10 minutes. Points raised are the project plan, work packages, division of labour in the group, time commitment, technical documents etc. To be able to give fruitful feedback, they have, in addition to reading all the documentation, also interviewed members of the other team. Further tothis there are teachers from the department attending the midterm workshop and they also have the opportunity to give feedback to the project teams.

Suggestion: Plan learning activities throughout the course in which students can learn from each other, in which students can act as "teachers", i.e. give feedback, hold lectures and presentations.

2.4.4 Ways of organizing lectures and meetings

Lectures on the subjects, topics and knowledge necessary for students to fulfil the project tasks can either be offered in a course antecedent to the project course or as part of it. As a teacher, you can plan these lectures in advance or you can let the students suggest topics while the course is being held, i.e. lectures-on-demand. And if students suggest topics that are not within your field, you can invite colleagues to teach in your course.

Savin-Baden (2003) describes different approaches regarding the role of the teacher/supervisor as quoted in Davis and Wilcock14. In project-based learning (case/task and discipline based projects) on the one hand, the teachers supervise the students and lectures might be offered to support the work of the students or it is assumed that the students use knowledge gained from previous courses. In Problem-based learning (problem based projects), on the other hand, teachers are more like facilitators and lectures are not commonly offered since students are expected to define their own learning needs.

Additionally, teachers in project courses will also arrange supervising or coaching meetings with the students. In these meetings, the role of the teachers also differs between a more active supervising role and a more passive coaching role.

An Example from Electronic Design illustrating the method of letting the students ask for lectures when they realise their need:

Lectures are offered when the students realise what information and knowledge they need, but it is important that the students have progressed to a certain point of the project and that they have had time to try to come to a solution by themselves. Students have requested and were offered lectures e.g. on how to write reports as well as on thermo dynamics, PCB layout and PIC programming. These lectures are a way to speed up the learning process by getting useful hints at the beginning of the learning process. Often these lectures turn into guidance directly when the need is discovered in any of the groups. It is always a balancing act on how much should be "given" and how much should be found by the students themselves, since one of the ILO:s and assessment criteria is "to identify and acquire relevant information".

An Example of teachers' coaching role from the course Lightweight Design/Naval Design:

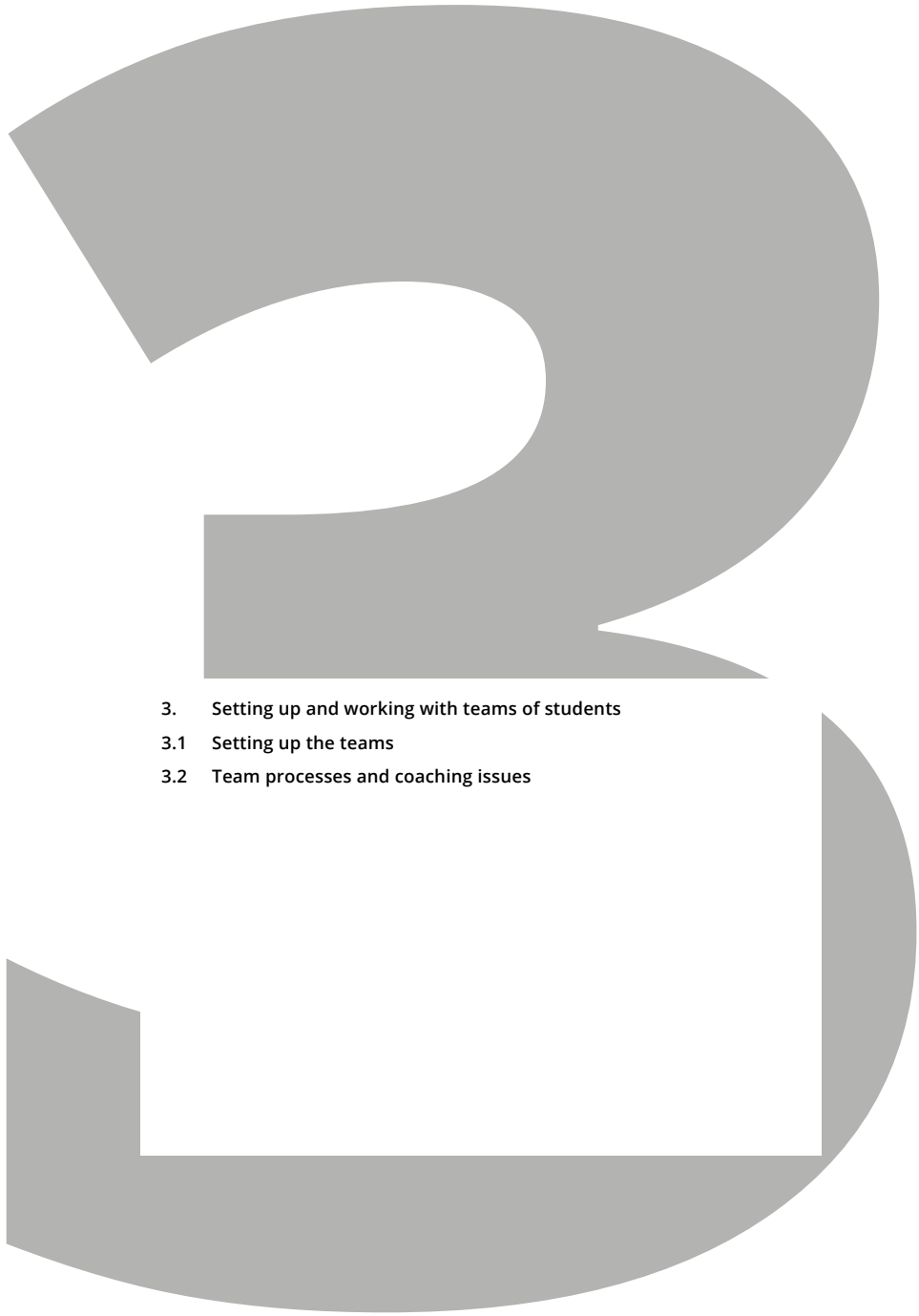
Meetings for all students are scheduled once a week and the students prepare presentations of parts of the project which they are working on. During the meetings, the students have the opportunity to ask questions and discuss issues that they find problematic. But, the teachers in this course avoid giving direct answers and solutions to the students. Instead the teachers are coaching them by asking counter questions e.g. what would be of most benefit to the project? The teachers say that sometimes it is difficult as a teacher not to give the answers,

but the purpose is to make the students own the process as well as the results of the project.

Suggestion: Let the type of project decide if and how you offer lectures and to what extent you will coach or give answers and solutions to your students. To prepare students for as many aspects of the project as possible, antecedent courses containing a number of topics such as team work skills or technical subjects can be offered. Furthermore, you can also give students an opportunity to ask for lectures when they realise they need the knowledge or skill in their projects. Besides lectures, project meetings should be held regularly. The meetings can be attended either by all students or by a representative from each team.

Notes:

Notes:



3. Setting up and working with teams of students

3.1 Setting up the teams

3.2 Team processes and coaching issues

3. Setting up and working with teams of students

In this chapter, we discuss the question of how teams should be built as well as team processes and coaching.

Cooperative learning has been shown to have positive effects on high quality learning; however, simply putting students in teams is not sufficient. The teacher needs to take factors such as student diversity, inter-disciplinary differences and students' previous knowledge and experience in teamwork into consideration. In fact, if the teacher does not take steps to assure that the groups develop into high-performance teams, the experience might even be disastrous.

In order for student teamwork to be efficient, teachers need to plan for how the students are to learn the skills required. It does not happen automatically. It is essential that the teacher:

- Introduce teamwork by explaining what is required to succeed e.g. to value team members unique competencies.
- Plan for teamwork outside of class in the schedule.
- Form the teams and make sure they are heterogeneous in competen cies and of an appropriate size in relation to the assignment.
- Establish the policies that will govern the teams operations and encourage the team members to formulate their expectations on each other, including what to do when a conflict occurs.
- Make sure that teamwork is continuously evaluated when it comes to progress and functioning.
- Plan for how to deal with interpersonal conflicts in teams when they develop.
- Is explicit regarding when and how the teacher can be contacted if something needs to be sorted out.

To support learning on teamwork skills, there are a number of tools on the market, e.g. the test Myers Briggs Type Indicator (MBTI) (21), aiming at increasing understanding of different roles and personality types in teams. MBTI has been used at KTH as well as at Aalborg University (10). Another tool is a test called Belbin's team roles (22).

3.1 Setting up the teams

The division of students into project groups can be determined by the teacher, the students themselves or jointly. A solution where all team members can

achieve the learning outcomes at roughly the same level of challenge and workload is desirable, but can be difficult to achieve. If the students get to choose for themselves, it is common that they are looking for friends or like-minded people because it's more convenient. This might be an advantage if the project task is relatively limited in scope and in cases where the assessment focuses on the outcome rather than the group's process. A homogeneous group often works more effectively in such forms, compared to a heterogeneous group (23).But if the project task is more extensive and complex, by having a heterogeneous composition the team members open themselves up for creativity and alternative solutions to problems.

To encourage heterogeneous compositions, the teacher should explore the students' background and abilities before project groups are defined. The cultural and social diversity in a heterogeneous group typically gives rise to more complex group dynamics, which is desirable in cases where the process is in focus. To reduce the risk of serious conflicts that hamper the work of the group, it is important that students are aware of and open-minded towards differences, and are encouraged to try to understand each other's perspectives when communication fails.

In larger projects, where different roles are necessary in order to organize the work efficiently, a challenge often emerges around the division of roles. How this is done can depend both on the nature of the intended learning outcomes and the composition of the team. Is it possible to reach the course learning outcomes in all roles? For example, if one of the ILOs is for all team members to gain experience of working in various roles, then this will be a guiding factor. But if it not, it can be beneficial to let the students choose their roles themselves. It can also be beneficial if it is a heterogeneous student group, since different members then can contribute according to their own conditions and thus feel greater affinity with the group at an early stage. In this context, it is important that group members communicate about different ambitions and take joint responsibility for ensuring that everyone gets enough challenge and a reasonable workload.

An Example of teachers dividing students into teams while students divide roles and change roles within the teams in the course Integrated Product Development:

Since we want heterogeneity among the students in the teams, the teachers divide them into different teams. We base the distribution on educational programme, gender and sometimes even grades. We can

also match according to which courses the students have taken to distribute competence, and complementary, the students do a team role test, Belbin's team roles (22). The results give us an additional basis to reach heterogeneity within the groups.

The students must themselves decide upon how to divide the different roles within the team. They usually solve it democratically; it is rarely the project manager who allocates roles. Groups structure the projects based on what they want to do and often students have preferences on which role they want to take. Sometimes we push students to test other roles as well and we support students to seek another role if they ended up in the wrong position.

For pedagogical reasons, we have large project teams with 12-16 students as this requires more organisation. We do not think that the students should be in the same roles throughout the entire project and therefore we conduct a reorganisation of the team. In this way, students can find new positions and learn about more than one possible role in a project. This takes some energy and focus from the product, but the students know that it will happen and it is an important part of the course and the ILOs. The course run over two semesters and after the first few months of the project, the groups need to change e.g. project manager and sub-team leaders.

Students working in their team, Integrated Product Development.

Team roles according to Belbin: (22) "Co-ordinator, implementer, specialist, completer-finisher, monitor-evaluator, resource investigator, plant, shaper, and team worker."

These team roles are not equivalent to the formal roles of a project team, rather they cover roles that are necessary to create an effective team. To make the team as effective as possible, all roles should be taken. However, one team member can have more than one role. An effective team should have at least four or five members (24).

For additional information on Belbin's team roles, see http://www.belbin.com/rte.asp?id=8

Suggestion: Before dividing the students into teams, consider the intended learning outcomes of your course. If you have an objective on performing the roles in a project, make sure that the students can take on the different roles of the project. When setting up the teams you can take what aspects of the project the students are interested in into account, but it is also a good idea to consider their competence, gender, and educational background, and sometimes even personalities, to make the teams as diverse as possible.

3.2 Team processes and coaching issues

A common model for team development (25) is shown in figure 1. If the students have enough time and support (or enough experience), and a project assignment that is well-designed for the purpose of creating valuable team processes, they can overcome the phases of looking at their own needs firstly, then being concerned with how the team functions, and finally being mostly focusing on looking at the task and how to solve it together. Sometimes a team can go through the stages forming, norming, storming and performing several times, sometimes they end up in one stage, and sometimes they never reach the performing stage, going back and forth between storming and norming for example.

During the forming stage, students can be very polite. They are normally more concerned with them-selves, how they act and talk. This stage is also called honey-moon. The supervisor can, besides talking about the assignment, and expectations, help the team members to get to know each other and discuss group dynamic issues that are natural and how they will be monitored.

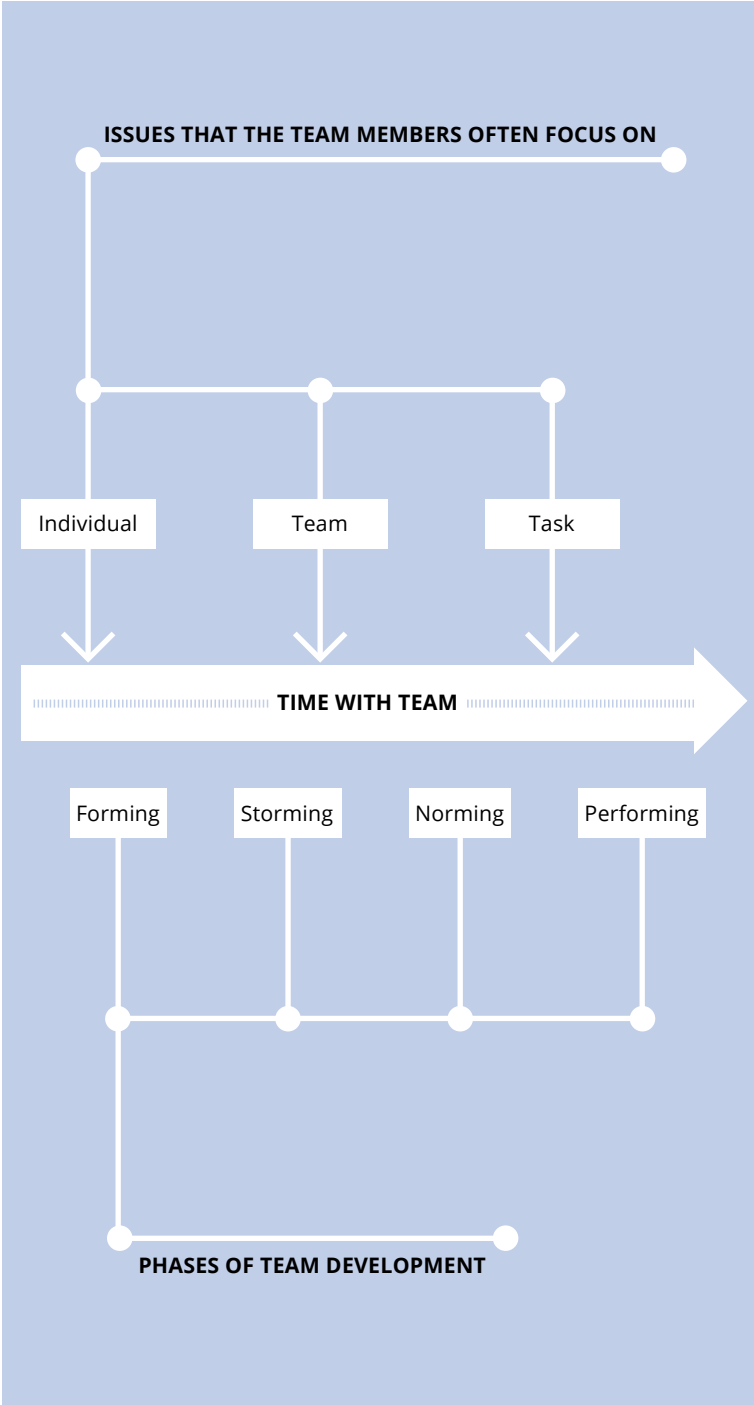


Figure 1: Stages of team development. (25)

Team-building and ice-breaking activity in Integrated product development. The student teams are asked to make sure the whole team gets from one side of the wall to the other, by climbing over it. No student can climb the wall on his/her own. By this, the teachers are aiming at helping the students to start trusting and helping each other. Photo: IPD coach

The storming stage often differs between groups, from dramatic to quite easy. Normally, issues and concerns about other team members, or about the assignment or the coaching meetings, are raised during this stage. If the supervisor isn't asking or looking for signs of storms within the group, there is a risk that the team keeps these issues to themselves. In this case, the student team might get stuck and not move forward to a high performance stage. There are some important signs for storms, or upcoming storms. Drops are when productivity or quality goes down. Plops are when you notice deadly silence in response to someone's ideas. This can cut off creativity from the group; reasons for it could include some students just wanting to get on with the work, or not all students feeling they belong to the team. When students have hurt feelings or frustration over, for instance, the project task, the team, or their own role in the team, you might experience a pinch here and there. Pinches can be formulated in sarcastic sentences, or shown with body language. When you as a coach notice a pinch, it's best to mention it. Otherwise it can blow up to a crunch where students leave a team, refuse to solve the task and so on. (26)

The supervisor's role is to support the team through the storming stage – as far as possible. The supervisor should not stay in it, or try to walk beside it (by for instance pretending they don't have any disagreements, or have made any mistakes), or try to solve the issues separate from the team work simplistically

(by for instance dividing tasks or switching teams) or over-dramatize the issues. Help the students to see further than today's issues, try to take your own emotions aside and don't run to conclusions too quickly. Students don't have to be happy with all their team members nor all tasks within the project, but respect and follow agreed rules.

Example of a team exercise: How I am in teams

Gibbs argue that as all students probably have experience from working in teams in different settings, such as in sports, education, clubs etc, they bring with them all kinds of feelings, thoughts and good ideas for how teamwork can or should be carried out. By bringing this out in the open quite early in the process, students and teachers can become more aware of themselves and each other and hopefully create a better start.

Students are asked to go through four stages in this exercise (27):

1. What teams I have been in: think on your own first, and then take turns with your team members and tell your stories.
2. Write your answers to the following questions on your own:
   In teams I tend to avoid…
   I like teams where…
   I don't like teams where…
   How I'd like to be in this team
   How I'd like this team to be for me
3. Each team member, one at a time, without interrupting each other, shares what they have written on the question sheet.
4. Finalize the exercise with building strategies to make the team successful.

Example on how students write team contracts from Lightweight Design/Naval Design:

The students write and sign team contracts that state rules for the project teams. Each group decides their own rules and the team keeps the contract for themselves, hence they are not collected by teachers. If there are problems in a team, the teachers remind them of their contract, and usually this works in the sense that the teams solve their own problems by themselves.

When students are focusing on setting up ground rules, and discussing how they can work well together as a team, they are in the so-called norming stage. As

a supervisor it can be fruitful to show different team work and communication models. By monitoring the task and role divisions, the supervisor can make sure that all students are involved in the project as a whole. Avoid letting so called draggers dominate and set the rules without including all team members. (26)

When, and if, the students finally are in a high performing stage, where all team members feel they themselves and all team members can contribute and learn from the work, it can be fruitful to have them discuss this and give each other feedback on these aspects. How did they end up in this stage? How will they use this experience in future team work? Can their experience be used somehow in other teams who are not so successful, yet?

Example of a team exercise: What's going right?

This exercise can be integrated in coaching sessions several times during a project course, making comparisons over the weeks possible. It could also be integrated on a study program level, so that students can compare different teams they have been in. If you prefer, you can change the name of the exercise into What's going wrong, and change the statements below accordingly. The original exercise, by Gibbs27, had this name, but we are suggesting that a more positive approach can make the exercise more constructive, and also make it applicable on successful teams.

Students are asked to go through three stages in this exercise (27):

• Use the checklist to analyse your team, on your own. Check all statements that you agree with, and perhaps you need to change the wordings so it fits better with your team. Add extra comments too if you like.

We listen well to each other
We can argue when needed, but also move on well in the discussions
We almost never interrupt each other
We are good at developing and encouraging each other's ideas, not just pushing our own
We almost never allow single team members to dominate
All of us contribute well
We are good at compromising
We are more focused on getting the job done, than concentrating on making impressions
We have clear tasks and objectives

We are almost always clear about what has been decided
We make it clear on who is to take action on decisions
We almost never put each other down
We try not to bring in irrelevant or unhelpful points to our discussions
We are good at recognizing that others have feelings about what is happening in the team

- Try to agree what strengths and problems the team have, by sharing your checklists and identifying the total score each statement has. You may need to be concrete and give examples when sharing your lists, both on good and bad team work signs.
- After you have agreed on what's going right and what's going wrong, decide what to prioritize and build a strategy on how to solve the signs of weaknesses. Also include a date when you will repeat the exercise.

For additional information on team development, see: 10 short films staging a team development process: http://archive.learnhigher.ac.uk/groupwork/episodes.php

Suggestion: To secure that the students learn about effective team work, it is a good idea to offer exercises throughout the course focusing on the team processes.

Notes:

Notes:

4

4. Assessing project work and solutions and evaluating the course

4.1 Formative and summative assessment
– feedback for learning, or feedback on learning

4.2 Assessment criteria

4.3 Individual assessment in a group setting5

4.4 Assessment forms:
Ways for students to communicate results and performance

4.4.1 Writing:
Reflections, log books, portfolios and reports

4.4.2 Prototyping

4.4.3 Oral presentation

4.5 IPR and Non-disclosure agreements

4.6 Evaluating and improving your course

4. Assessing project work and solutions and evaluating the course

In this chapter, there is a focus on the outcomes of the project, on how to communicate the outcomes and on the assessment of project work and solutions. There is also some information on Intellectual Property issues. We also discuss the evaluation of the course.

Even if we like to believe that every student is motivated by some inner force to study every course in the degree program, the truth is not that idealistic. How the students are assessed, both formative and summative, during the courses affect how much effort they put in and how much (and what) they learn. Choosing assessment activities that are meaningful and worthwhile can be the key to motivation (4).

4.1 Formative and summative assessment – feedback for learning, or feedback on learning

When students are working in project based courses, their knowledge and skills will frequently be "public", or under observation. During coaching sessions, mid-term presentations, and laboratory sessions and so on, you will see how well they understand and apply different knowledge fields. By this, you as a teacher will be able to guide students quite closely in their learning progression. You might want to add an extra lecture on a specific topic or create a workshop on for instance how to write a good report. All these types of assessment situations, where you and students have insights into where students are in relation to the learning outcomes, and time to develop further before the final grade/mark, are different forms of formative assessment.

The heart of formative assessment is feedback. Feedback can be divided into three different aspects: feed up, feedback and feed forward (28).The figure below shows how the three aspects all are important to improve learning and development. We need to have an idea of what we are supposed to learn and achieve (feed up). The analysis of what we have done, what steps we have made, how we carried out a certain task and why we chose the steps we did, is helping us see how well we relate to the expectations (feedback). The central part, the feed forward arrow, can help supervisors and students to realize and remember that the priority when giving feedback is to plan for the coming steps we need to take.

When giving feedback, Hattie and Timperley (28) notice in their research, that too much emphasis is placed on inefficient matters for a good learning progres-

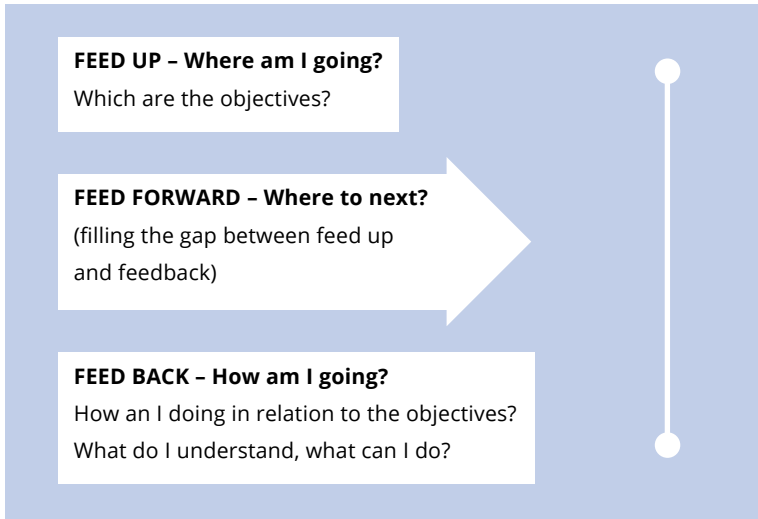


Figure 2: Three main questions in feedback. Based on Hattie and Timperley. (28)

sion. They distinguish four levels of feedback, with the first giving the least for learning, and the last being what feedback should be most about.

1. Feedback about the self as a person - The least effective feedback is looking at the person how he/she is (clever, lazy and so on), and not what has been done.
2. Feedback about the task - Here the emphasis is on the task at hand, be it a mathematical problem solution, a written essay or a programming code and so on. The feedback will mainly focus on right/wrong, good/bad, and there is a risk that students will not gain much from this type of feedback.
3. Feedback about the processing of the task - Instead of looking at the solution to the problem, the discussions can deal with how the students worked with the problem. How sources were found, what implications were there along the way and so on. This is much more effective for the learning progression.
4. Feedback about self-regulation - This fourth and most effective level of feedback raises the discussions above the task at hand and looks at students' development of skills for lifelong learning. How do I know what I know, what strategies do I have for learning and how can I be flexible with different types of tasks? All this is helping students to develop their metacognitive skills, which will help them perform much better on different tasks.

When doing the summative assessment, it's the final time before the final grade, for students to show their knowledge and abilities in relation to the learning outcomes. This can be carried out in a variety of forms as well, such as final reports, oral presentations, demonstrations, debates or perhaps by showing your best work in a portfolio.

Both forms are important for learning and to assure that students have reached the intended learning outcomes. Very often in project courses, the formative and summative assessment tasks are interrelated. Teachers need to be clear on how and when different activities in the course are a basis for the final grade, since, in order for students to learn as much as possible, they will need to openly identify their knowledge gaps. And this will happen in a more honest and safe manner, if the assessment form is completely formative.

In big classes, many teachers use anonymous ways to formatively find out about students' knowledge, by for instance anonymous mini-exams or clickers. In project courses, where you normally work much closer to the students, when coaching teams of students and following their work, being anonymous isn't feasible or appropriate.

Creating a safe atmosphere is crucial. One way can be to let the students know that the coaching sessions are not a basis for the final grade. Another way, and perhaps more fruitful, can be to have the guideline that active involvement from the students' side during the coaching sessions (lots of questions and discussions, and being well prepared) is a basis for the final grade. This can help the coaching sessions become a good learning experience, and open up discussions among students who might believe they should have the perfect solution or answers to the problem at hand.

An Example of formative and summative assessment in Lightweight Design/Naval Design:

At the start of the course we communicate the intended learning outcomes and encourage the students to gather evidence of how they work with the ILOs in their portfolios. In the middle of the course, we have a formative assessment. We have added the formative assessment at this stage since they, at the end of the course, will be assessed in a way they have never experienced before. The formative assessment provides students with lots of feedback. At first, the students will write a one page summary – a narrative – each in which they should refer to all

ILOs and describe how they have approached the ILOs. They should also refer to a reference list where all reports and presentations etc that they have completed in the course are listed.

The document is submitted to the teachers who bundles them all together and send out all narratives to all students in the course. They also receive a form in which each student will provide written feedback to all the other students in terms of their theoretical contribution, practical contribution and social contribution to the work of the group. The students will then receive all the feedback they have got from other team members. Eventually, they will write a reflection on what they have learned and what went less well. The students also grade each other, information that they will get in aggregated form. The process ensures that we have all the feedback, we can see what grades they gave each other and we can catch up with students who are not performing. Benefits of the arrangement include that students are forced to reflect and they also receive feedback after half of the course.

At the end of the course, the process is conducted once again in a summative manner. Grades in the course are based on an overall assessment of the portfolios, written feedback, the feedback received and the proposed grades as well as the observed work effort in the project.

Suggestion: Use both formative and summative assessment since both forms are important for learning. Both of them also secure that students have reached the intended learning outcomes. As a teacher, you have to be clear on how and when you formative and/or summative assess the students. The students need to know when they are assessed for the final grade, and when they safely can show their knowledge gaps.

4.2 Assessment criteria

Linked to the question of which criteria to apply when assessing the project tasks, is the question of whether the students need to be successful as regards their solution/product or if they can get good grades even though their product fails.

Comment from a teacher in Lightweight Design/Naval Design:
As a teacher you should of course not ignore whether the product is successful or not, but you have to think about why things are going well or poorly. Sometimes the product is successful because of luck,

or because of individuals who have done well, rather than due to a successful process. There are lots of other things that affect, such as relations and conflicts in teams. Students often see the product as the most essential part of the course, but the product is only one part of a course that covers several other aspects such as project methodology and learning outcomes.

The terms “assessment criteria” and “grading criteria” are similar in meaning and can often be used interchangeably. In Sweden the assessment criteria should be related to the ILOs. The learning outcomes identify the essential learning to be achieved to merit the award of credit. The assessment criteria should specify how satisfactory performances of the learning outcomes are to be demonstrated.

The purpose of assessment criteria is to establish clear and unambiguous standards of achievement in respect to each learning outcome. They should describe what the learner is expected to do, in order to demonstrate that the learning outcome has been achieved. The assessment criteria are expressed as qualitative levels of achievement in respect to the learning outcomes. Preferably the levels should be discrete, but sometimes it is necessary to use adjectives or adverbs describing the quality in a continuous scale, for example “satisfactory, good, and excellent”. The number of different levels of each criterion should be adapted to the different learning outcomes, which standards are suitable to put on them and how they could be assessed. The number of levels may well be lower than the number of different grades.

Besides the grading criteria, a formula or matrix describing how the final grades depend on the achieved levels, according to the grading criteria, has to be defined. Assessment criteria should encourage learning at the appropriate level, by making the requirements clear. They are valuable for the teacher when constructing and marking assessments. They are also define what the teacher thinks are the main points of the course, which will help the teacher when describing what is important in the course when talking to students or colleagues.

For additional information on assessment criteria, see: David Gosling and Jenny Moon: “How to Use Learning Outcomes and Assessment Criteria”, http://www.seec.org.uk/publications/how-use-learning-outcomes-and-assessment-criteria

Example of assessment criteria from Electronics design:

We use assessment criteria both to assess but also to guide the students. There are seven criteria in total: 1 - be able to participate in and conduct project groups, 2 - show analytic ability by dividing a problem into smaller sub problems, 3 - show ability to use relevant prerequisites to solve the task, 4 - show ability to independently search or ask for relevant information to solve the task, 5 - orally present a technical product and discuss the work, 6 - be able to produce a well-disposed technical report with good linguistic and scientific quality, and 7 - show ability to review your own and others work. In each of the criteria, there is a table showing what has to be done to reach a certain level, e.g. as regards criteria 5 - Orally present a technical product and discuss the work:

Excellent: Shows good ability to orally present with clear arguments and analysis. Shows good ability to discuss the work.
Good: Shows good ability to present and discuss the work.
Sufficient: Shows ability to orally present the work.
Insufficient: Lacks the ability to orally present or discuss the work.

As regards the 7th criteria, to show ability to review own and others work, the following is stated in the instructions: To reach this aim for reviewing your own and others work, the following instructions are valid. During the project work the student should keep a diary and time report (optional). These should be available for the examiner to read. The interval depends on the length of the course. Notes should be taken every 15-20 hours or at least once a week. This is to minimize the risk that important information will be lost. The diary should contain the following (not everything every time): 1. Project progress and project work: - Actual performed work, - Collaborative partner, who did I work with?, - What progress is done?, - What problems do I experience in the group?, - Have we solved any problems lately?, 2. Analytical ability: - Why did I do this? How does it fit into the total project, the final prototype?, - What problems are unsolved?.

An Example of an evaluation committee in the course Degree Project in Biotechnology:

In this course several supervisors are involved supporting and supervising the project teams, including senior faculty and doctoral stu-

dents. These supervisors form a “supervisor team” and seven of them are included in our evaluation committee in which we discuss the students’ grades. The advantage of having a teacher/supervisor team is that it gives us a space for discussing our teaching and for assisting each other if there are problems in the project teams, e.g. conflicts or other issues. We also offer a course on supervising to our doctoral students to make them prepared for the task.

Suggestion: In order to make the assessment and grading of the students appropriate make use of assessment criteria based on the intended learning outcomes.

4.3 Individual assessment in a group setting

According to the Swedish Higher Education Ordinance, students must be graded based on their individual knowledge and skills, even though they are conducting their work in a team. There are many ways for students as individuals to share how well they have reached the ILOs of the course. In the section on formative and summative assessment above, the example from Lightweight/Naval design shows how each student writes a one page summary where they discuss and show their own learning progression in relation to each ILO of the course. This type of written assignment is quite common, and can be extended to individual reports or portfolios.

Assessing each individual’s level of achievement of the course ILOs can also be carried out orally. During the project course, this can be carried out formatively by creating cross-groups, so that one student from each team meets members from the other teams and present their work. Summatively, on the final presentation, this is also feasible, by for instance giving each student a specific area to discuss and present during the final oral session, independently. You might want topics to be “all programming we used in our project”, “the methods we used and why”, “how our knowledge in Mathematics have helped us”, “how to search and collect appropriate information”. By assigning topics to each individual quite late in the process, you can help them stay aware that they will need to understand the complete process.

An Example of individual assessment in a group setting from Degree Project in Biotechnology:

In this course, we have had assessment criteria from the start, but we have added the individual criteria to secure the assessment of students

on an individual basis. Hence, the assessment criteria are now both on group level and on individual level. The group level criteria are: process; engineering-related and scientific content; and written presentation. The individual level criteria are: individual activity; oral presentation; individual reflection; and individual opposition. For example, the criteria Engineering-related and scientific content is assessed in the written report, the oral presentation as well as during the meetings with the supervisor. The criteria aligns with the following ILOs: 1. Apply knowledge and skills acquired during the studies on issues in biotechnology, 2. Formulate and attack a technical problem by applying the relevant methodology, and 3. Identify the need for further knowledge and continually develop the skills through advanced studies in a specific field.

As we have a team of supervisors, they form an evaluation committee in which the grading process is discussed. Still, the evaluation and grading process is challenging and you have to keep discussing the process with students and supervisors.

Example of assessment in the course OpenLab with students from several universities:

This course is offered in cooperation between several universities. The students are mixed in trans-disciplinary teams, though each university has its own course, rules and regulations. Hence, each university has its own assessment procedure which means that students in the same team will be assessed differently.

Suggestion: If you are supposed to grade the students on individual basis, when formulating the assessment criteria, make sure you state criteria both on group level and on individual level. Clarify the criteria to the students in the beginning of the course.

4.4 Assessment forms: Ways for students to communicate results and performance

Communicating knowledge, methods, findings and questions, whether orally or in written form has a formative as well as a summative purpose. The summative purpose is to show learning and results before the final grade. The formative purposes are to ensure that students develop their under- standing within the field, as well as their communication skills. The develop- ment of successful communication should be seen in a wider perspective, for instance from

a whole study program perspective, since developing good writing skills is a process that takes time. Lots of feedback and advice, and plenty of variation in the lengths of the texts as well as forms and audience, will promote this process.

The importance of being able to communicate findings and conclusions effectively cannot be underestimated. In working life, this skill can be crucial for success. (29) Project-based courses have the advantage of providing excellent opportunities for training communication skills in a realistic context. In the selection of presentation media, one could take into account the environment in which students can be expected to work after graduation. For example, written reports and oral presentations are generally used. In some context, such as in product realisation and in architecture, prototypes and various forms of exhibitions are used. In an educational context, it is important to note that the documentation and presentation of findings and conclusions is also an important learning opportunity. This work should be integrated with the continuous work during the course to stimulate reflection. This also provides an opportunity for regular feedback on work from teachers and/or students, which will help project teams to understand if the work is progressing as expected.

4.4.1 Writing: Reflections, log books, portfolios and reports

Structured reflections can help students to find connections between pieces of knowledge and abilities and to get hold of the bigger picture. Students can for example reflect upon how the team is developing, how the project work is progressing and how roles in the team are changing as well as on how the student as an individual is experiencing the team work. There are a number of options when it comes to where the reflections can be written, e.g. in log books, essays as well as in reflective journals or portfolios. There are also several options regarding if and how the reflections are read by the other students. For example, one may read the text for a small group of students (and teacher/s) and accessing their knowledge and experience of how things can be understood and viewed by others. All groups should undertake the same procedure in turn. What should be noted is that the reflection meeting is not a place for opinions, only for experience and knowledge; it is absolutely not a place for critique. It is a place for creativity and learning where everybody should feel safe to open up and discuss in a safe atmosphere.

A portfolio is a document in which students can gather artefacts, reflect and develop their capabilities over a long time period. In design domains, projects can

be conveyed in a number of different ways without the divide of right/wrong solutions. Gathering artefacts of projects achieved is also showing one's design ability that hardly could be described otherwise. The portfolio can be divided into three levels: The public, the restricted and the personal. The public is open for the world and show achievements and artefacts. The restricted is open for the working groups, like peers and teachers, here you can motivate your choices and get feedback. The personal level is where you reflect about your strengths and shortcomings and how you intend to develop your design ability and this level can be open only to yourself.

Log books are normally used over a short time period, e.g. during a course. Log books can also be divided into levels: the group log book, available for peers and teachers, and the individual log book, available only for teachers (30).

For additional information on portfolios, see https://arc.uchicago.edu/reese/projects/using-portfolios-promote-knowledge-integration-engineering-education

An Example on assessment forms in Integrated Product Development:

Students previously wrote about their work in a log book. The log book contained diary entries, which included both reflections on what they had learned and information about things that were done, which was rather confusing for the students. Now, we have separated it into two parts; lessons learned and a portfolio. Lessons learned contains what the students have learned; it is handed in regularly and is included in the assessment. The portfolio contains what has been achieved, is handed in twice per semester, and the final submission is included in the assessment.

Having a final report of the project work as the major assessment task is very common in project courses. In some courses, the final report is interwoven in several learning activities throughout the course, so that the teams write drafts that are used in coaching sessions, and in peer learning activities. The decision on structure and contents can be made by the department, the teacher or by the students themselves.

Students report writing skills can be trained through different activities. Often the supervisor gives feedback directly to each team's drafts. By doing so, you

might end up with lots of detailed work, and students only adjusting according to your feedback, without actually improving their writing skills. One way to improve this method can be to give general feedback to the whole class, and ask them to improve their texts accordingly.

Other forms of training writing skills can be to hand out students earlier work, both strong and weaker texts, and ask students to read and give feedback on the texts. You can also design a short activity where you ask all students to list a title, headings and subheadings that would be needed in a specific report to, for instance, convince a target group of an urgent matter. This activity could be blended with a peer learning activity, where students read and discuss each other's lists.

First Year Project Course in Electrical Engineering:
The students prepare a poster and a final report. For the poster, the students get guidelines on how to design the poster, e.g. which headlines to use (title of the project, names of team members, the problem/task, and the solutions/results) and format. For the final report, they get instructions integrated into lectures on project planning. Additionally, the students also give an oral presentation of their projects. All these tasks align to the ILOs on communication (i.e. to present technical information in oral and written form, and to create the fundamental documents required for planning, following up, and finishing a project).

Suggestion: To support the students' development of communication skills, assessment forms containing writing reports as well as reflective texts in e.g. portfolios are suggested. Consider your intended learning outcomes and the overall perspective before deciding on type of report, to assure the students' progression of communication skills during the education.

4.4.2 Prototyping

Prototypes are made to figure and communicate functionality; they can be physical or analytical/virtual. Prototypes also work as concrete evidence of the progression of the specific project. The process of prototyping includes team members collaborating in a number of iterative loops in which reflecting, discussing, listening and trying again are essential aspects. (31)

Berglund and Leifer (32) discuss the benefits of using prototypes in educational settings: "By using prototyping as a core activity in the courses, communication

Students working on their prototype, Integrated Product Development.

between project members, potential users and industrial partners becomes relatively easy, less abstract and creates fewer unnecessary misunderstandings". They also touch upon the balance between focusing on the product and the learning:

> "Prototyping supports idea generation, conceptualisation, design exploration, evaluation, communication, and construction. Because it can be an overwhelming undertaking to create a single prototype that strives to achieve all of these goals, it is important to be focused on the objectives. From an educational viewpoint, achieving learning objectives overshadows the importance of technical performance, even though they tend to go hand in hand."

Examples of prototyping in Integrated Product Development:

Throughout the program, the students produce several prototypes from idea to final prototype. In the beginning these are simpler prototypes in paper, plastic, wood, and cardboard to quickly get feedback about the product from the development team, users and project partners. Subsequent development steps can contain more elaborated 3D prints based on CAD. As the project progresses, the prototypes become functional to enable testing of the functions. The ultimate goal is to have a full functional product/prototype when the project is completed.

Degree Programme in Design and Product Realisation:

Each year, all the students in the programme present their products/prototypes at an exhibition called "DoP-Expo". Here, exciting and creative projects are presented, projects that students, individually or in groups, worked with during the fall semester in grade one, two and three.

Suggestion: As stated earlier, start with the ILOs when preparing the methods you want to use in your course. Also consider the presentation methods used in the relevant field of industry/work, since this will help students develop relevant skills. If prototyping and the methods used in prototyping are required in the profession, assure that the students will have several opportunities during their education to learn.

4.4.3 Oral presentation

Students performing their final presentation, Future of Media.

Oral presentation activities are excellent to promote learning within the field and for you as a teacher to understand how well students have grasped their project work and the knowledge field. Oral presentations can vary in infinite ways. Each coaching session involves oral presentations with findings and questions, and by making sure all team members are involved in the discussion, they are constantly trained to speak about their work. If you create cross-group sessions, where each team member presents their work in front of a group of other students, you will also make sure all students have time to practice oral presentation skills in quite small and safe settings.

Several types of role-play activities can be fruitful for developing oral presentation skills and the knowledge within the field. This can be in the format of a political debate, a discussion held at a company with different staff members who are solving a case, or an invented discussion between academia, industry and society.

By looking at video clips with the students on different forms of oral presentations, you can create a list of important aspects to consider when talking in front of different target groups. These aspects can also be a basis for the feedback and assessment criteria within your course.

Example of oral presentation in the course Future of Media:
At the end of the course, the students make a final presentation. Most project teams also make a film that illustrates how they have dealt with their project task and the films are showed during the presentations.

Teachers from the department as well as a jury attend the final presentation session. The jury contains teachers, a guest lecturer, representatives from industry, as well as alumni. The jury will give feedback on the students ' presentations and on their solutions. The audience also includes students from first, second and third grade of the programme.

Suggestion: Let the students present their projects, at least to each other, but preferably also for an external audience, e.g. with representatives from the industry or external partners as this will prepare students for future work.

4.5 IPR and Non-disclosure agreements

When taking part in a project-based course, it is likely that Intellectual Property (IP) in some form is generated. This IP might be suitable for further development and/or commercialization, and therefore it is important to be aware of and manage IP in an early stage of the work. IP stands for Intellectual Property which means any intangible property that is or may be of value. The definition of IP in the KTH Policy for managing intellectual property is; “IP in the context of this policy means intellectual property that is or may be subject to intellectual property rights according to applicable law such as, but not limited to, patent, copyright, trademark and design as well as everything that represents a result of intellectual work such as, but not limited to, inventions, prototypes, models, texts, compilations, calculations, information, materials, data, know-how, methods, drawings etc.” (33)

It is important to have a clear picture of the prerequisites of the project, for example if there are any agreements or provisions that affect the work and the results generated. To regulate ownership of the results/IP in the group at an early stage is important in order to avoid conflicts and misunderstandings later on. Intellectual property law states that the inventor has ownership of the IP generated. If there are two or more inventors, the IP is jointly owned. Confidentiality agreements is a good way to make sure that the group can work and communicate freely, and at the same time make sure that the results are protected.

Ownership and management of IP as a result of project-work varies considerably and this is best handled on a case-by-case basis. KTH provides support for this through KTH Innovation and the legal department. It is recommended that you seek out this support. Basic rules and principles for management of IP is regulated in the KTH Policy for management of intellectual assets (33); http://intra.kth.se/regelverk/policyer/policy-for-intellektuella-tillgangar-skapade-vid-kth-1.456590.

4.6 Evaluating and improving your course

For university teachers, course development often involves incremental and continuous changes. Most teachers are interested in high-quality education and are eager to enhance their courses. At the same time it is clear that there are many obstacles, for example, time and resource scarcity. Further obstacles arise from a conflict between balancing research and teaching activities. In order for pedagogical development to take place there is a need for things such as an active interest on behalf of management and also dialogue with colleagues on matters of education (30). Good communication with students and colleagues is often crucial to success. Course evaluation could serve as the starting point for such a dialogue. Furthermore, teachers get inspired from research and others' pedagogical development efforts when planning course development.

An example of a course evaluation method:

the LEQ Learning Experience Questionnaire (34), is developed at KTH and is based on CEQ Course Experience Questionnaire (35). The LEQ is a tool that examines the student's experience of the learning environment in the course. It consists of a number of statements and a few open questions. Examples of statements are:

- The work I did was challenging in a stimulating way
- It was clear to me what I was expected to learn
- I worked in a way that helped med develop my own understanding

of the content

• I got regular feedback that helped me see how I was doing

Examples of open questions are:

• What was the best aspect of the course?

• What would you suggest to improve in the course?

The purpose of evaluating the learning experience is to find aspects of the course that need to be improved.

An example of course evaluation methods in Electronic Design:

Course evaluations mainly point to practical deficiencies which need to be addressed. Course evaluation meetings, on the other hand, where both teachers and students participate, can address development needs in both an overall level and a detailed level. Therefore, we use a standard evaluation form, but also try to complement with a more informal evaluation meeting where other aspects can be pointed out. We discuss issues as theory and practice and what the students learned, team work and how the teams were set up, the projects planning model and whether they could work according to the model, and the role of the teacher/supervisor.

Suggestion: Use course evaluation to improve your course. One option is to use questions and statements as in the LEQ. If there are issues that the students rate low, e.g. if the students do not find the course challenging or if it wasn't clear what they were expected to learn, these issues need to be handled and improved. Preferably, you can discuss these issues with your colleagues and then you can support each other in course development. Besides using evaluation forms, also consider to arrange evaluation meetings with the students.

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5. References

5. References

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34. LEQ, https://www.kth.se/social/group/guide-to-challenge-d/

35. CEQ, http://www.ceq.lth.se/

Additional links:

- Solar powered boat: http://kthsolarboat.se/index.php
- Sanitation in Tanzania: http://www.aalto.fi/en/current/news/2013-07-03-002/
- Stanford methods to improve design thinking practice: http://dschool.stanford.edu/use-our-methods/

- Brainstorming: www.me.umn.edu/courses/me2011/handouts/brainstorm.pdf
- Scrum and Kanban: www.infoq.com/minibooks/scrum-xp-from-the-trenches and www.infoq.com/minibooks/kanban-scrum-minibook
- Belbin's team roles: http://www.belbin.com/rte.asp?id=8
- 10 short films staging a team development process: http://archive.learnhigher.ac.uk/groupwork/episodes.php
- David Gosling and Jenny Moon: "How to Use Learning Outcomes and Assessment Criteria", http://www.seec.org.uk/publications/how-use-learning-outcomes-and-assessment-criteria
- Portfolios: https://arc.uchicago.edu/reese/projects/using-portfolios-promote-knowledge-integration-engineering-education
- Web version of this Guide: https://www.kth.se/social/group/guide-to-challenge-d/

Guide to Challenge driven Education

How can university education incorporate societal needs that strengthen learning outcomes and render graduates skills for the labour market? This Guide has compiled different examples from challenge driven projects in higher education programmes. The aim is to inspire teachers, students and 'challenge owners' to jointly develop solutions to technical, societal and sometimes very complex problems, in a way that incorporates demands on higher education quality.

Cases from international and interdisciplinary collaborations are found that have provided students with the skills to take on open ended, real world challenges.

The Guide is developed to motivate to challenge driven education, to propose important 'rules of the game' and to contribute to a platform for a shared understanding between teachers, students and challenge owners in different contexts.