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Implementing 21st century skills in education at NTNU and DTU

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ABSTRACT

NTNU (Norwegian University of Science and Technology) and DTU (Technical University of Denmark) have established compulsory courses to provide students with interdisciplinary teamwork skills:

- The students work in interdisciplinary teams
- They work on real-life challenges
- At the same time, they take a meta-perspective on their own cooperation in the project.

NTNU's Experts in Teamwork course is compulsory in all master's programmes and programmes of professional study at NTNU and is offered to 2,500 students each year. About 100 members of the teaching staff are involved, and 200 learning assistants are employed each year.

Innovation Pilot is a compulsory course in all bachelor of engineering programmes at DTU and is offered to approximately 800 students per year. Some 20 members of the teaching staff are involved, and 10 learning assistants are employed each year.

In both courses, the students develop teamwork skills by reflecting on and learning from specific situations of cooperation in carrying out a project in interdisciplinary teams. The students' own team experience forms the basis for their development – how they and others contribute, and how the team functions, are subjects of discussion, reflection and feedback. The courses provide students with 21st century skills and are an important contribution to the engineering education field.

1 INTRODUCTION

1.1 21st century skills and their importance

A key social mission for higher education is to contribute with competences that uphold society and develop it further. From society and industry alike, there are increasing demands for skilled and well-educated engineers who can develop new solutions through innovation, and for creating successful innovation interdisciplinary teams with a focus on solving problems are necessary.

A key question is: How can we best help and prepare our students to cope with the more uncertain, rapidly shifting, competitive and inter-connected world?

Different studies conclude that students are lacking in some basic skills as well as a large number of applied skills called the “21st century skills” [1]:

- Oral and written communication
- Critical thinking and problem solving
- Professionalism and work ethic
- Teamwork and collaboration
- Working in diverse teams
- Applying technology
- Leadership and project management

In Scandinavia several universities working with experienced-based and interdisciplinary learning have established an “Experts in Teams” network founded by The Nordic Council of Ministers (Nordplus). The network's main objective is to train students to utilize their academic competence in interdisciplinary settings in order to reach enhanced project outputs. This is achieved by focusing on teamwork skills. The work methods in the Experts in Teamwork course at NTNU have been developed over two decades and have influenced the development at other universities. The network has established a conference called “Interdisciplinary Teamwork Skills for the 21st Century” (Its21), and initiated the process of developing cross-Scandinavian learning material and practical training of teachers in interdisciplinary teamwork skills; see: <http://nordicexpertsinteamnetwork.org/>

This paper presents two initiatives aimed at giving students interdisciplinary teamwork skills. Although the origins of Experts in Teamwork at NTNU and Innovation Pilot at DTU are different, the courses have ended up fairly similar. Both courses bring students together from different study programs, include working with external companies to solve challenges provided by the companies, and also has focus on the collaboration in the team.

It is a fact that active and collaborative learning practices have more significant impact on students' performance than any other variable. By engaging students from different study programs and place them into an interdisciplinary learning environment, the idea is that they will make use of different viewpoints and different competences in order to solve case problems for the involved companies. Thus, both courses focus to a large extent on the “21st century skills gap”. By training the

students' interpersonal collaborative skills, it is our belief that the training may also facilitate innovative processes.

1.2 Introducing interdisciplinary skills in education

Experts in Teamwork was established in 2001 as a compulsory course as part of a major revision of the Master of Science program at NTNU. The course was developed in response to a request from the industry in Norway for students with the necessary skills and tools to work across disciplinary boundaries [2]. The course required a radical change of teaching, from lecturing and instructing to facilitating, i.e. to facilitate the development of abilities in cooperation, reasoning and decision-making in teams. At that time, the change was hard for many teachers, and it took several years of planning and testing to implement the desired changes [3]. In 2002, the board of the university decided that Experts in Teamwork should be included in all programmes of study at master degree level.

In 2014, the first version of the newly developed CDIO-based bachelor of engineering programmes (B.Eng.) programmes was launched at DTU [4]. The programmes were the result of a comprehensive merger process of former diploma programmes, namely the programs at Engineering College of Copenhagen (now DTU Diploma) and the Technical University of Denmark. The most significant new activity in the programmes was the introduction of a compulsory course in innovation in the later part of the programmes. The course was named Innovation Pilot. The idea behind this course is to give students the opportunity to collaborate on interdisciplinary real-life projects. This course strengthens not only innovation skills but personal and interpersonal skills as well [5]; [6]; [7].

1.3 How can we train the development of teamwork's skills?

Students develop teamwork skills by reflecting on and learning from specific situations of cooperation in carrying out a project. Interdisciplinary teamwork is used as an opportunity to develop collaborative skills that make teamwork more productive. Open-ended challenges from civic and working life form the basis for teamwork, and the results achieved by the teams are used to benefit internal and external partners.

The learning method is experience-based. The starting point is students' experiences together with each other "here and now". This means that they relate to situations arising in the team, they share their thoughts and feelings about each other's patterns of behaviour and approaches to situations in their teamwork, and then reflect on this.

Interdisciplinary teamwork skills can be described as both knowledge of the prerequisites for effective interdisciplinary teamwork, and skills in finding solutions to a variety of open problem formulations in cooperation with people from other disciplines. It includes skills to identify key aspects of the teamwork, and reflect on the essence of these aspects in order to develop the team. It also includes skills to

change teamwork patterns to make the team more productive and create a positive, constructive and social climate for the cooperation.

Relating to each other in an ongoing work process is intellectually and emotionally demanding and causes the students to become deeply involved in their teamwork. This creates learning experiences that help to improve the learning outcomes. When theory is presented to the students, the main aim is to contribute to a greater understanding of the group dynamics in their own team.

To make experienced-based learning work well, the teacher roll has to change accordingly. It is not enough to simply tell the students to work together. The teachers will also have to be experts at the same 21st century skills they are imparting to their students and be aware of their role as facilitators. This necessitates training of the teachers, also with regard to facilitating the innovation process (train the trainers).

1.4 Two cases – NTNU and DTU

Experts in Teamwork at NTNU

Experts in Teamwork is a 7,5 ECTS compulsory course for all master's degree students across all eight faculties at NTNU. The students are organized in classes called "villages" of 20 to 30 students. Each village is taught by a member of the teaching staff and two learning assistants acting as facilitators, and has a broad overall academic theme (real-life challenge) that forms the basis for the students' project work. The villages may have external partners that represent the theme and who may be advisers and recipients of the students' work.

Innovation Pilot at DTU

Innovation Pilot is 10 ECTS compulsory course in the final year of all 18 study programmes of the bachelor of engineering programmes at DTU. The students are divided into classes of up to 60 students called "labs". Each lab is allocated to a company or several companies providing open-ended real-life challenges for the students, and is run by a facilitator team consisting of two facilitators or one facilitator and one learning assistant.

Common for the two courses

The overall learning outcomes and methods are more or less the same for both courses. The students work in interdisciplinary teams with five to six participants from diverse programmes of study. The student teams are mixed from across all programmes of study, they are allocated to the labs or villages on the basis of their preferences, and no more than two students from the same study programme is allowed in each team. The teams hand in both a project report and a team process report (reflection report) at the end of the course.

The learning assistants in both courses are students employed on part-time basis with training in observation and facilitation. The facilitators' role is to initiate

reflections by highlighting aspects of the team dynamics that may be less evident to the team itself and to guide the students through the innovation process.

2 METHODS

In this section, we compare the two courses with respect to intentions behind the courses, the learning method, and training of the facilitators and how the learning objectives are achieved.

2.1 Intentions of the courses

The course description for Experts in Teamwork specifies that relevant problem areas from civic and working life should form the basis for the students' project work, and that the students should reflect on the social usefulness of their project. Interdisciplinary project work in teams with such goals helps to create a deeper understanding of the relationship between project work and innovation.

In Innovation Pilot the companies provide the teams with open-ended projects which take their starting point in actual challenges observed by the company. The teams explore the challenge by doing research into the problem, the needs and the context, including the use of different tools to re-define the problem definition before focusing on the problem solution. This will train the students in how to work systematically with innovation as an exploratory process. Furthermore, the course provides training of communication of needs and solutions to relevant stakeholders by pitching, prototyping and written presentations [6]; [7].

The expected learning outcomes in the two courses particularly contribute to the development of what is called the general competence (central parts of 21st century skills), and is formulated:

General competence developed in Experts in Teamwork

- *Students have extended their perspective on their own specialized knowledge in their encounter with skills from other disciplines. They can communicate and apply skills they have developed in their own field in collaboration with students from other disciplines.*
- *Students can collaborate with people from other disciplines, and they can contribute to realizing the potential of their combined interdisciplinary expertise.*

General competence developed in Innovation pilot

- *Enable you to solve complex challenges in companies through using your engineering knowledge and thereby train an innovative mindset.*
- *Provide insight and experience in working and collaborating across engineering disciplines as part of your engineering professionalism.*

Even though the courses are on different levels, the overall intention of the courses based on learning outcome is fairly similar. For both courses it includes the skill related to communicating and using discipline knowledge together with others to

solve complex challenges. It also includes the skill of collaborating across disciplines.

2.2 The learning method

The basis for the students' development of skills in cooperation is their own experience from working together in the team – how they and others contribute, and how the team functions as a dynamic whole. Experts in Teamwork is based on Kolb's pedagogical model of experiential learning [8] in four phases:

1. Students gain practical experience in interdisciplinary teamwork.
2. They reflect on how their teamwork is influenced by their own behaviour patterns and attitudes, as well as those of others.
3. The students identify and describe their teams' behaviour pattern based on their reflection and team theory and discuss needed changes to be made to make the team more efficient.
4. The students try out new behaviours to improve the dynamics in the team when they continue work on their project. The effect of the changes has to be evaluated in retrospect.

Innovation Pilot also apply the Kolb learning cycle but has a more explicit focus on the innovation process than the team cooperation.

Most of the teaching staff in Experts in Teamwork and Innovation Pilot have little or no previous experience in the type of learning activity that is central in both courses, and most of the learning assistants in Experts in Teamwork have not taken the course themselves because it is late in the study programme. The teaching staff in both courses is therefore offered experience- based training.

2.3 Learning activities

Real-life teamwork situations are the subject of discussion, reflection and feedback throughout the Experts in Teamwork and Innovation Pilot courses. Structured social exercises, questionnaires and facilitation are used to encourage progress, effectiveness and innovation. Theoretical knowledge is woven in to provide a perspective on teamwork quality.

Experts in Teamwork

Students in Experts in Teamwork write both personal reflection papers and team-based reflection papers on the interaction in the team (thoughts and emotions) [9]. To support their personal reflections, each student receives a reflection journal [10] which includes information about reflection writing and blank pages for their own reflections. In teams, the students share and discuss their personal reflections and evaluations. This involves becoming aware of the teams' behaviour pattern in decision making, participation, conflict resolution, information sharing, taking care of their well-being and motivation among other things. For this to happen, it is important that the village leader and learning assistants create a safe space for learning.

The team process report that the student teams in Experts in Teamwork hand in at the end of the semester builds on the teams' reflections [9]. In the report, the students reflect both as a group as well as individuals on their experiences of specific situations, which leads the team to construct general principles that can be applied in future settings. The report addresses the innovation process, the team process and the learning outcome. Theory is used as a tool to illuminate and structure their experiences.

Innovation Pilot

Likewise in the Innovation Pilot course, the teams and the students individually write logbooks that describe and reflect on the course activities and how they have been handled in the groups and for the individual. The logbooks provide the basis for the final reflection and learning reports, which the students hand in at the end of the course.

In the final reflection and learning report, the teams evaluate and reflect on the interdisciplinary process, the role of themselves and others in the innovation process, and how they have managed professional and personal differences, and how their own and others' competencies have been used in the solving of the company challenge [6], [7].

Common for the two courses

Reflection is both a learning activity during the semester and a skill that the students develop for use throughout their lives. The overall learning goal is that the students should be able to identify and reflect on key aspect of a teamwork process to develop the team to make it more productive and create a positive, constructive and social climate for collaboration.

2.4 Training of the staff

Both learning assistants and village supervisors in Experts in Teamwork are jointly offered two-days training programmes every year. The training is intended to develop skills in experienced-based learning, and to build effective, productive and confident teams consisting of a village supervisor and two learning assistants. It is especially important for the facilitator teams to work well together when they are to stimulate students' development of teamwork skills. The learning assistants are in addition offered a one-day practical seminar with roll-play based training of facilitating teams.

In Innovation Pilot the learning assistants have recently taken the course Innovation Pilot themselves, for which reason they can relate many of the "challenges" to their own situation and provide supervision based on their own experience. The facilitators and the learning assistants in Innovation Pilot are also offered a two-day training course.

The Experts in Teamwork academic section has developed a handbook for the village supervisors and learning assistants [11]. The book describes the learning

methods and provides information on how to plan and carry out the learning activities and contains several group exercises and more. The same book is used in parts in Innovation Pilot.

3 DISCUSSION

3.1 Learning of teamwork skills

It seems to be a widespread belief that collaboration is learned as a "by-product" of work in groups during education or in the workplace. Teamwork competence at the level of Experts in Teamwork or Innovation Pilot is not fully learned through practice-makes-perfect. Our experience is that learning through practice alone is not sufficient to meet the needs of working life for skills in interdisciplinary cooperation. Reflection on the collaboration and peer-feedback do not normally take place without facilitation, and thus normally do not take place in the workplace. Such skills call for formal education. The facilitation in Experts in Teamwork and Innovation Pilot makes it "permissible" and "secure" to talk about the relationships, and helps the group see what is happening between them. The facilitators create the conditions for the students' experienced-based learning in a way that provides insight into the prerequisites for effective, innovative and productive teams. Together with the facilitation, development of a cooperation agreement and structured social exercises in the team help to improve students' learning outcome.

3.2 Feedback from the students

Each year we investigate students' perceived value of Experts in Teamwork through both quantitative and qualitative data. The quantitative data have been collected through a course evaluation instrument from 2007, with response rates above 80% in all years.

Since 2007, the students in Experts in Teamwork have been asked about their overall satisfaction with the course [12]. There is a clear increase in students' overall satisfaction from 2007 to 2014, and from 2014 more than 90% of the students have reported somewhat satisfied, satisfied, or very satisfied on a five point scale. The steady increase in student satisfaction is the result of a continuous development of the teaching method and training of the teaching staff. Also, it has taken many years to establish a climate, and a culture, where students (and teachers) not only accept, but also buy into the collaborative format of the course.

The students have also been asked to evaluate their own experience in the Experts in Teamwork course and the extent to which it will help them in the future. In general, the students perceive their Experts in Teamwork experience to be relevant for later work life and feel that it prepares them for future tasks. Especially receiving feedback from other students on their behaviour pattern is considered very valuable. The students also acknowledge the importance of the Experts in Teamwork experience and believe that it has given rise to new thoughts and ideas that will be valuable when working in teams in the future.

Below is a statement from an Experts in Teamwork brochure from a student who has taken the course:

Through [Experts in Teamwork], I have been able to develop my personal characteristics to a far greater extent than I had expected at the start of the project. I have gained greater insight into my positive aspects. At the same time, I have had the opportunity to work with things that used to be difficult for me. To give feedback and to receive it in a good way has been challenging. Through the exercises and the group interaction we've been through, we gained experience with this, and I emphasize this experience as the most positive thing that [Experts in Teamwork] has given me.

Feedback from society

In 2005, a Norwegian report from an independent research institute concluded that: *"[Experts in Teamwork] thus succeeds in giving the students more of what is often termed 'generic' knowledge, i.e. knowledge that is common to all disciplines, and especially in the field of 'socio-communicative skills'" [9].*

3.3 Need for training of the staff

At NTNU and DTU the Experts in Teamwork and Innovation Pilot courses act as a platform for academic development that is unique. The teaching staff at the universities usually has no experience in creating the conditions for the students' experience-based learning in ways that provide insight into the prerequisites for effective, innovative and productive teams. Therefore it has been necessary to provide training for the teaching staff to enable Experts in Teamwork and Innovation Pilot to function as intended. This training also represents a significant contribution to development of the teaching staff, training the universities' academic employees in alternative learning methods. At NTNU 100 staff follow the train every year.

For other institutions that are planning courses to give their students interdisciplinary teamwork skills, we strongly recommend to start training the teachers in experienced-based learning.

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