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"From terrible teen to terrific trainee”:

Norwegian cases of innovative workplace-school collaboration to educate young people to become skilled workers in modern manufacturing industry

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Abstract:

Contemporary debates over "the factory of the future" show that industries will need vocational workers that are empowered and skilled to act as decision-makers and controllers, holding technical and social skills of a high standard. Further, industrial development demands enough supply of skilled vocational workers. In Norway, a parallel concern is drop-out rates from upper secondary education. Consequently, it is of joint concern for the manufacturing industries, the secondary education system and the welfare state alike to ensure that young people choose vocational education and that they finish their education with skills and motivation needed to contribute in the "future manufacturing factory". The research question is the following: How can lower secondary schools or vocational colleges collaborate with industrial companies as to motivate young people to become vocational workers who are educated in the technical and generic skills needed for future manufacturing industries? With an action research approach, we explore on experiments of such innovative collaboration. We find that workplace-learning motivates young people to learn both trade specific and generic competencies. Thus, we argue that the lower secondary school-system must be included in what traditionally has been vocational education-workplace collaboration. Further, we find that the learning of future skill requirements presupposes collective learning processes and authentic problem solving. Finally, we argue that competencies fit well as an inclusion in both the social- and technological dimensions of socio-technical systems design, but more research is needed on the mechanisms by which competencies become "inputs" and "outputs" of future work designs.

Keywords: Vocational education, future competence requirements, workplace learning, school-company collaboration.

Introduction

At present there is a huge debate over the transformation of working life. Technological changes like digitalization, Industry 4.0, automatization and robotization are already having great impact, and one radical part of the debate is whether there will be any jobs in the future working life (Frey and Osborne 2013). A parallel debate, and the one which forms the background for this paper, is what competences are needed in a fast-changing global economy as for companies to develop their competitiveness and capacity to drive innovation.

Within this debate, the concern over skill supply is vital. In the EU white paper, *A new skills agenda for Europe* the Commission suggests policies for strengthening human capital, employability and competitiveness for Europe. In 2016 more than half of the 12 million long-term unemployed were considered low-skilled. Further, many people work in jobs that do not match their talent. At the same time, 40% of European employers have difficulty finding people with the skills they need to grow and innovate (p. 2). For the manufacturing industries the challenges are primarily on the supply of vocational workers. Within the context of Norwegian working life, Statistics Norway have made the estimate that Norway will be lacking 90 000 vocational workers in 2035 (Cappelen, Gjefsen, Gjelsvik, Holm and Stølen 2013). The shortage in the manufacturing industries will show particularly for electricians, manufacturing operators and construction workers. A parallel concern to this challenge is drop-out rates from upper secondary education, or lack of recruitment to vocational study programmes. It is of joint concern for the manufacturing industries, the secondary education system and the welfare state alike to ensure that young people make informed vocational career choices and that they leave their education with skills and motivation needed to contribute in the "future manufacturing factory" and engage in life-long learning.

Although practitioners and academics at present seem to agree on the skills needed for future manufacturing, the challenge on how to educate future and present workers remains a tricky one. Vocational education systems play a core role as a link between the general education system and the labour marked as to give young people the opportunity to make informed career choices. However, according to Messmann and Mulder (2011), it is difficult for young people to select an occupation and find apprenticeship training because of a shortage of training positions and because of new job profiles with higher job requirements. In addition, companies have higher demands on apprentices such as being competent, motivated, communicative, flexible and even mobile (Messmann and Mulder 2011, p. 64). In countries like Norway, Austria, Denmark, Germany and Switzerland the dual VET system depends on the willingness of firms to participate (Eichhorst et al 2015). The system is set up as a shared commitment between the school system and work life as to educate students to meet the changing market requirements. Vocational colleges provide the school-based part of dual apprenticeships and the firms must meet certain technical standards to be accredited to offer apprenticeship contracts. However, as Eichhorts et al (2015) argue, while dual training has clear advantages from a societal and individual perspective, it totally depends on firms' commitment to participate.

The challenges of connecting schools and work life are twofold as the rapid changes in the labour marked and work environments also require that vocational colleges and teachers must be responsive towards societal transformations to provide optimal learning opportunities and job preparation for students (Nijhop and Streumer 1994, Messman and Mulder 2011). Wesselink et al (2009) argue that in order to improve the connectivity between learning in school and learning in the workplace three aspect of the quality of this connectivity is important: authenticity, self-responsibility, and the role of the teacher as expert and coach. In a study where their interviewed students, teachers and workplace training supervisors they found that because the stakeholder groups hold different conceptions of workplace learning and often do not communicate adequately about mutual responsibilities, the implementation of the three aspects of competence-based education has not significantly improved the connectivity situation (Wesselink et al 2008 p. 19).

Within this context this paper explores upon three ongoing experiments of innovative workplace-school collaboration aimed to give pupils in lower secondary school, upper secondary vocational schools colleges and apprentices a real-time encounter with the skills required in modern manufacturing. As partners in the research project "SKILLS: Future Industrial Worker in Skilled Practice"[36] , and which will be described more fully in chapter three, the enterprise partners reported a great concern for their industry in general, and their company in particular, for how to ensure that young people who choose to go for a vocational education have realistic perspectives of what it takes to be a machine operator or an electrical power installer in a factory producing high-quality products for the global marked. Hence, the aim of the experiments has been to prepare the pupils and apprentices on the skill requirements and effective work processes in a modern industrial workplace. The first experiment involves pupils both at lower secondary school and upper secondary vocational school level, where they work together with technical staff in the participating companies to design and produce a mechanical- and electrical vehicle. This experiment is designed to have teenagers at lower secondary school follow what we denote "the value chain of becoming skilled", which will be described in chapter 3. In the second experiment, pupils in the second year at their vocational education are constructing and installing a power electrical system "in-situ" in an electrical power company. For three days they are guided by the company's workplace trainers in solving the task of mechanical- and electrical assembling of a switchboard. Finally, the third experiment is that mechanical operation apprentices spend three months, out of their two-year apprentice contract time, in the company's R&D department as to develop skills in product innovation processes.

Theoretical framework

Competence requirement in future manufacturing work

Knowledge needs in working life has gained considerable attention in research during the last 10-15 years. The European project "Key Competence Network on School Education" (KeyCoNet) identified a set of key competences for the future in national educational systems including 1) communication in the mother tongue, 2) communication in foreign languages, 3) mathematics, science and technology, 4) digital competence, 5) learning to learn, 6) social and civic competencies, 7) sense of initiative and entrepreneurship and 8) cultural awareness and expression (Arjomand et al. 2013). In addition, the EU recommends that critical thinking, creativity, problem solving, risk assessment, decision making, and constructive management of feelings, are added to the list of key competencies. Further, the project "Assessment and Teaching of 21st Century Skills" (ATC2015) identified four groups of skills: 1) ways of thinking, 2) ways of working, 3) tools for working and 4) living in the world (Binkey et al 2012). An Official Norwegian Report (NOU 2014:7) presents similar conclusions. However, the Norwegian panel makes a distinction between distinct competencies and broad competencies. While skilled trade, along with e.g. ICT knowledge, the natural science and mother tongue- and foreign languages are distinct competences, it is the broader competencies like learn to learn, critical problem solving, cultural awareness, skills in collaboration and communication, that are the dominant future competencies, necessary both in working life and in the civic society.

In their survey on competence need for Norwegian manufacturing industry and the construction industry Solem et al (2016) found that mastering of trade specific skills was as important as the generic skills. The novelty of Solem et al's research (2016) is the identification of three specific competencies: 1) understanding the company's value chain of production, 2) how to initiate innovation processes, and 3) how to act autonomously in daily operational activities without supervision. They denote these competences "value creation skills", "innovation skills" and "responsible operating skills". The companies participating in the survey also highlight that an important content of trade specific skills includes knowledge on how to operate safely, as occupational injuries is critical in both manufacturing- and construction industry.

[36] Financed by the National Research Council of Norway. Project number 247747.

Another stream of research addresses the working life itself. Danford et al. (2008) and White et al (2004) argue that the interest for highly qualified workers can be understood as a response to changes in the market and technological conditions. Consumers demand a broader range of high-quality products and services and there are continuing developments in ICT that can enable more flexible manufacturing systems. Such conditions put new demands on worker skill and flexibility (Danford et al. 2008).

Organisational researchers have claimed that skills inside a company are key to success (Bessant 2003). A manufacturing company that starts developing high-quality products and services must increase its response and innovation rate. To do so, it must abandon the tight control-oriented approach and rely on workforce agility and responsibility. This requires higher skills and other kinds of skills among the employees. Then, companies can profit from teaching operators to solve technical problems as they occur, instead of calling in specialist technicians for problem solving and delaying the production (Wall, Corbett, Clegg, Jackson, and Martin 1990). Because companies rely on skilled workers in high-tech manufacturing, workplace practices centred on employee participation are assumed to pay off. Ravn and Øyum (2018) argue that new modes of manufacturing operation result in traditional blue-collar work moving into areas of work previously held solely by salaried staff. Consequently, within this context the educational system for vocational education must offer a curriculum reflecting the organisation of modern manufacturing production lines.

Workplace learning of vocational expertise

The recent debates on skill requirements to cope with future work life complement debates on ways of learning and the epistemology of competency. Hodkinson and Issitt (1995, in Wesselink et al 2009 p. 22) state that "competencies are integrated constructs that are a function of the context in which they are applied. Without a context, competencies are too generic and have little meaning". This statement relates profoundly to the way vocational education is supposed to enable the students to acquire the competencies needed in their future professions, and hence the focus is on competencies and not qualifications (Biermans et al 2004).

The approach to vocational training differs greatly between European countries (Nyen and Tønder 2014, Eichhorst 2015). In Norway, vocational training usually involves two years in a vocational school followed by a two-year apprentice contract in a company. The first year in school provides general education alongside introductory knowledge of the vocational area, while the second-year curricula are more trade-specific. As a contrast, Sweden has a three-year high school programme with a strong emphasis on general theoretical and academic knowledge. The vocational training takes place mainly at school and apprenticeship scheme plays a marginal role. In recent years, however, Swedish education authorities have made attempts to develop a stronger apprenticeship scheme. The scheme has primarily been perceived as an offer for school-tired students, not as the development of highly skilled workers. The German dual-model on the other hand has shown to be more effective than more school-based models to ease the transition to labour market (Eichhorst et al. 2015). Here, the student is an employee of the company from the beginning and receives tasks according to her or his growing abilities. If a company is willing to make an employment-contract with the student after his dual education time, the company will get an employee who knows the company's workflow.

Workplace-based learning and workplace training are terms used to describe the workplace as a learning environment, as opposed to formal learning (Pylväs et al 2017). The system of vocational education as briefly outlined above, relate to a socio-cultural theory of workplace training. In this perspective learning is becoming a process located in the framework of participation rather than within the learner, even if it does not replace notions of individual learning (Hager 2013 in Pylväs et al 2017). Lave and Wenger (1991) and Brown and Duguid (1991) have proposed that learning happens in everyday interactions and through participation in communities of practice. Learning is happening as part of a process in which learners move from peripheral participants to full members of the communities of practice. In their study of Finnish apprenticeship training stakeholder's perceptions of vocational expertise and experiences of workplace learning and guidance, Pylväs et al (2017) found that being offered authentic work and collective support by experienced workers was crucial. However, they found that in order to become engaged in the learning process and to become active members of a work community apprentices were in a need of strong self-regulatory skills even during the training. They conclude that workplaces provided fruitful learning possibilities for those apprentices with strong motivation, volition and ability to self-reflection.

In her study on bakery apprentices Chan (2013) discuss identity formation processes of becoming a baker and eventually being a baker. She states that "learning to become trade workers requires learning, consolidating and applying ways of doing, thinking, feeling and being (Chan 2013 in Chan 2015 p. 336)". An important point of view raised by Chan is that much of the research done on learning as becoming, Lave and Wenger's communities-of-practice alike, is in the perspective of older and experienced adults and that we need to know more on learning through the perspectives of young people. One study that has explored the notion of identity within young students' vocational aspiration is by Davis and Tedder (2003 in Chan 2013). Their conclusion, that students' vocational aspirations were "inextricably bound up with other aspects of their lives, with issues of identity, with becoming a person" (p. 3), supports research to be undertaken on how people 'become' in terms of vocational identity.

Due to the discussions above it seems critical that workplaces must continue their emphasis on taking responsibility for providing vocational-workers-to be learning opportunities in authentic work situations. Within the sector of manufacturing industries, it is likely that authentic work as 'learning-sites' will become even more critical to learn the competences needed for future manufacturing work. As pointed out it is a knowledge gap on how to involve youngsters in work-place learning to activate their opportunities to make informed career choices. In the rest of this paper we consequently outline and discuss three innovative cases on how workplaces and schools can collaborate on this challenge.

Research method

The methodological approach in the experiments is action research oriented (Greenwood and Levin 2006) with an emphasis on cogenerative learning processes (Elden and Levin 1991). As discussed by Holtgrewe et al (2015) the choice of which method to use depends on the research question and the rationale behind it but also on which role the researcher shall have in the research project. They state that the logic behind interactive methods is co-generation, and where "the researched are research partners". Hence, in our research the researchers' role has been to initiate dialogues between the companies and the schools and facilitate their process of setting up the experiments. The input to setting up the dialogues has been contemporary debates over future skill requirements in manufacturing industries and the industry's experiences on the skill level among vocational education students, apprentices, and recruitment strategies. The aim of the experiments has been to gain knowledge on how manufacturing workplaces, vocational schools and lower secondary school level can collaborate in new ways which will benefit the pupils, teachers and the workplaces alike, and what is required for innovative collaborative practices to be institutionalized.

Table 1 below gives an overview of the various participants in the experiments:

Table 1: Overview of the participant in the case experiments of innovative workplace-school collaboration.

Case:	**Participants**	**Research method**
Case 1: "From terrible teen to terrific trainee	• 9th grade pupils on lower secondary school (N=16) • Students on vocational education college (N=10) • Teacher in lower secondary school **(N=1)** • Teacher in vocational school **(N=1)** • Production engineers in company **(N=2)**	Focus group interviews Observation Process facilitation
Case 2: "Situated learning of power-electric skills"	• Workplace trainers **(N=6)** • Pupils in 2nd year at vocational college **(N=15)** • Teachers in vocational college **(N=3)**	Process facilitation Self-reported evaluation from students
Case 3: "Blue-collar R&D apprentices"	• Apprentices within CNC machining **(N=2)**	Semi-structured interviews

The cases are thoroughly described later in this chapter. In all cases we have used process facilitation techniques to involve the workplaces and the schools into reflection processes on how to set up new learning opportunities. Data sources are interviews and observational data from Case 1, interview-data from semi structured interviews in Case 3, and the pupils' self-evaluation data from case 2.

Table 2 below summarizes the stages of conducting interviews in case 3, "blue-collar R&D apprentices", and the research methods used to accomplish the experiments and to gain data on the results. As this experiment is still ongoing the findings are preliminary although providing valuable insight on what role workplaces can take in initiating innovative learning processes together with schools, and to some extent what the pupils and apprentices report on their learning.

Table 2: The stages and content of interviews with the CNC-operators participating in R&D activities as part of their vocational education

CNC machine operator R&D apprentices		
Interview 1 Before the R&D work placement	**Main focus:** • To learn about the apprentice's expectations	**Interview guide, main questions:** • What are your expectations for working at the R&D department? • What do you expect to learn? • What do you know about innovation?

Interview 2, 3 and 4
During the R&D work placement
	Main focus:
	• To learn how the R&D department have organized the placement
	• To learn what the apprentice have experienced so far
		Interview guide, main questions:
		• What has the placement been like so far? Please give examples of ordinary tasks, or incidents that have happened.
		• Please describe your normal workday at R&D
		  ○ What are your areas of responsibility?
		  ○ How do you get tasks?
		  ○ How does a workday at R&D differ from working in the production department?
		• Have you collaborated with the engineers at R&D? What has that been like?

Interview 5 After the R&D work placement	**Main focus:** • To learn how the R&D department have organized the placement • To learn what the apprentice have experienced and what he/she has learned	**Interview guide, main questions:** • What has the placement been like? Please give examples of ordinary tasks, or incidents that have happened. • What have you learned during this placement? • Has anything been different than you expected? Has anything been difficult? • How do you think your experience with sitting in at the R&D department could affect your cooperation with the engineers at the company? • Could anything been done differently during the placement? • Do you think the company should continue offering apprentices to sit in at the R&D department? Why/why not?

The apprentices' workplace trainer		

Interview 1
Before the R&D work placement
	Main focus:
	• To learn about the CNC machine operators' expectations
	• To learn what plans the R&D department have for the apprentices during their stay there
		Interview guide, main questions:
		• Why do you think it is important for the company that apprentices sit in at the R&D department?
		• What are your previous experiences working alongside apprentices?
		• What expectations do you have for having apprentices here at the R&D department?
		• What are your plans for the apprentices during their stay here?
		  ○ What tasks will you give them?
		  ○ Will you set any goals for them?
		  ○ What will be your role as a trainer?
		• What do you think the apprentice will learn by working here?
		• Do you think the staff at the R&D department could learn anything from having apprentices working here?

Interview 2 After the R&D work placement	**Main focus:** • To learn how the R&D department have organized the placement • To learn what the apprentice have experienced and what he/she has learned • To learn what the staff at the R&D department has learned	**Interview guide, main questions:** • What has the placement been like? Please give examples of ordinary tasks the apprentice has been given, or incidents that have happened. • What have you learned during this placement? Do you think other staff at the R&D have learned anything? • Has anything been different than you expected? Has anything been difficult? • How do you think this experience could affect the R&D departments collaboration with other parts of the company? • Could anything been done differently during the placement? • Do you think the company should continue offering apprentices to sit in at the R&D department? Would you like to continue being a trainer for them?

Cases of workplace-school collaboration

The SKILLS project[37] is an R&D project financed by the Research Council of Norway and three global industrial manufacturing companies with sites located in the middle of Norway. Our funding- and collaborating partners in SKILLS are the local sites. The project also involves three upper secondary vocational education schools, as well as one start-up company developing digital learning platforms. The primary objective of SKILLS has been to develop new theories, methods, and models for high-skilled vocational knowledge practices in the factories of the future. A key goal[38], and which form the basis for this paper, has been to develop a systematized model that describe vocational education as enabler for future vocational work in manufacturing, and to develop a framework for coaching in practice that enable future vocational work in manufacturing. Within this context the three cases which

[37] The project started in 2015 and will end in 2019.

[38] In the research proposal the objectives of SKILLS are formulated as:
1. Establish an **empirical foundation** by synthesizing prior knowledge on vocational work in future manufacturing and extend this knowledge through case studies.
2. Develop a **systematized model** that describe vocational education as enabler for future vocational work in manufacturing.
3. Develop a **framework** for coaching in practice that enable future vocational work in manufacturing.
4. Design an **overall system** for future vocational work in manufacturing. The design will include the arena/interface between school, company, unions, management and apprentices, and how to use technology as enablers for future high-skilled vocational work.

will be explored in this chapter are experiments launched as collaborating initiatives between companies, upper secondary vocational schools and two lower-level secondary schools. Seen as one innovative effort within the SKILLS project, all three experimental cases either have involved lower secondary school pupils, students in upper secondary vocational schools, teachers, workplace trainers, company representatives from the shop-floor union, HR-department and production departments, and the researchers.

Figure 1 below illustrates what we have denoted "the value chain of becoming skilled". Norwegian youngsters spend three years of compulsory lower secondary school, and three months before the end-date they apply for their next education in upper secondary school. Either they apply for university-preparatory curriculum or a vocational school. After two years of vocational school the pupils start on a two-year apprenticeship contract in a public- or private company, depending on their trade specialisation. Within this context the hypothesis in SKILLS have been related to test if the steps between these educational systems can be organized so that young people can make informed career choices so that companies can recruit vocational students who have a high level of inner motivation and knowledge on what it takes to be a future expert, into apprenticeship.

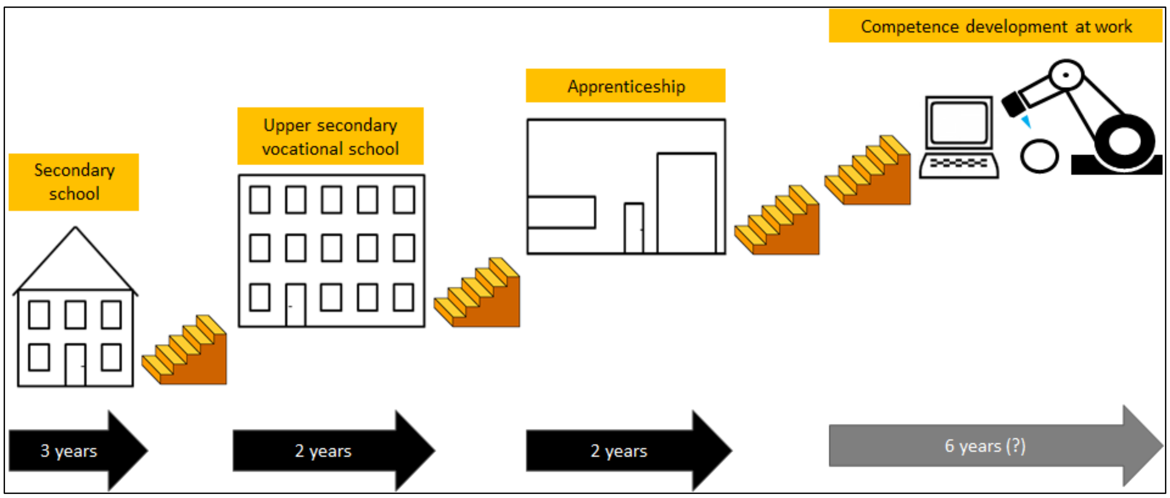

Figure 1: "The value chain of becoming skilled"

This value chain of becoming skilled has been the point of departure for the experiments which are presented below. The research question for the experiments was the following: How can school-workplace collaboration motivate young people to become vocational workers who are educated in the technical and generic skills needed for future manufacturing industries? Within the context of figure 1 the experiments have thus aimed at reducing the steps between the various school levels, learning contracts and manufacturing workplaces.

Case 1 is about collaboration between a lower secondary school, an upper secondary vocational school and a company, while case 2 involves an upper secondary vocational school and a company. Case 3, however, is about how a production company has redesigned their apprenticeship program so that production operator apprentices learn the competencies of collaboration, communication and parting in innovation practices by working in the R&D department for three months in their two-year apprentice program.

Case 1: "From terrible teen to terrific trainee"

Figure 1, the value chain of becoming skilled" was developed by the research team and the participating companies and upper secondary vocational schools alike in the early phase of the SKILLS research project. The companies and vocational schools argued that innovative workplace-school collaboration must involve the lower secondary school level as it is on this level the pupils apply for a college education. Thus, the schools, companies and society benefit from young people making their choice based on motivation for learning.

The experiment “From terrible teen to terrific trainee” is collaboration between one of the companies participating in the SKILLS project, a lower secondary school and an upper secondary vocational school. The goal for this experiment was to give lower secondary school pupils an opportunity to make an informed career choice through getting a better understanding of what it is like being a vocational education student and what working life would look like. Related to figure 1, the aim of the experiment has been to give the pupils a glimpse into what it is like to walk the two first stairs.

The experiment started out in lower secondary school, where the pupils were given the worktask of making a raft. It was predefined that the rafts should be made of a plastic pipe system and wood, as the two main regional companies and hence workplaces, produce these materials. In the beginning, the students worked individually with their ideas, and after a few weeks they were placed into four groups. Each group had to develop all their ideas into one concept that they would continue to develop further. When each group had decided on one concept, engineers from the partner company helped the students develop their concepts even further by asking questions about the rafts and making suggestions on how to improve them. When the concepts were finalized, the engineers made 3D-drawings from the pupils' hand-made drawings, included technical specifications, and produced plastic pipes to be used in the construction of the drafts. The pupils presented the drawings to vocational education students, who got the role as the pupils' mentors (alongside the teachers) during the process of building the fleets. The vocational education students also produced some of the parts which were to make up the draft's construction.

Case 2: "Situated learning of power-electric skills"

As discussed in chapter 2, Solem et al's (2016) research on skills needed in future construction- and manufacturing work, competencies in mastering the basis for the study program are as much important as generic competencies. This is in line with what Wesselink et al (2007) call Aspect 1 of competence-based education: The competencies that are the basis for the study program.

Within this context the case called "situated learning of power-electric skills" were launched as a joint initiative by a power electric manufacturing company and an upper secondary vocational school offering studies in electrical installation and maintenance. With this basic vocational education, the students can proceed with apprenticeship within various areas. The company offers apprenticeships in power distribution, where a key work task is to produce and install, both mechanically and electrically, switchboards for power distribution. In the experiment "situated learning of power-electric skills" teachers and company workplace trainers collaborated on designing an authentic work task for a power distribution fitter. Then, a group of 12 pupils spent three working days in the company's production department to solve the task in an authentic situation. During the task performance the company's workplace trainers were the pupils' teachers, and the schoolteachers were shadowing the training instructors to observe their way of engaging the pupils into the learning activity.

The company is an attractive employer for apprentices within this field and has for years offered several apprenticeship contracts to pupils from this vocational college. The experience of the workplace trainers is, however, that when the pupils have finished their school-based education and enter apprenticeship they lack fundamental knowledge on handling the modern equipment necessary to perform the work tasks of producing a switchboard and a power distribution unit. The vocational school agrees on this competence gap but lacks financial resources to invest in modern tools and materials. Further, the learning goal of the national curriculum for electrical installation and maintenance do not specify what competencies are needed in tool handling. Consequently, the aim of the experiment was to train the pupils in handling modern realistic perceptions on the work tasks and the area of work responsibility for a skilled power distribution fitter in this company. The teachers and workplace trainers designed the experiment according to the following learning criteria:

- The pupils' learning should aim at learning:
    - how to use a torque wrench when screwing nuts,
    - proper use of wheel discs,
    - electrical power wire preparation and -handling,
    - transformer construction (including Al/Cu connections).
    - mechanical installation of a switchboard into a power distribution unit
    - learn how to use modern tools and equipment and authentic materials
- The pupils should solve their task by spending three full-time working days in the company's production department.
- The workplace trainers should guide the pupils in their work, while the schoolteachers observe how the trainers work in engaging the pupils in a learning process taking place in an authentic work situation.
- Afterwards, the produced switchboard and the power distribution unit is given to the school as a gift from the company as to be used in later teaching activities.
- During the winter the workplace trainers will visit the school to observe how the teachers work with the pupils.

Case 3: " Blue-collar R&D apprentices"

As discussed above, competencies in critical thinking, creativity and problem solving are recommended by the EU as key competences for the future in national educational systems. Further, Solem et al's (2016) study on critical competencies for skilled workers in the construction- and manufacturing industry identified competencies in engaging in innovation processes and knowledge on the company's value creating processes as critical. Within the Norwegian dual system of vocational education, the students spend two years in school and two years as apprentices. The company involved in case 3 in our research, employs CNC (Computer Numerical Control) machine operator apprentices.

The national curriculum standard for CNC apprentices[39] includes two levels of competence requirements: 1) production technology and 2) quality assurance and documentation. Further, five generic competences are specified, all related to varieties of digital competence and mother tongue communication skills. However, there are no explicit references to what we in this paper have discussed as future competencies in engaging in or initiating production innovation, and more specifically the competency of collaborating with technical staff.

In order to test how CNC-machine operator apprentices can learn how to engage in activities directed towards innovation of mechanical products, this company have set up a pilot experiment motivated by being upfront in ensuring that future operators have competencies in innovation- and value creating processes. The core of the experiment is designing their CNC machining apprenticeship contract to include a three-month period of sitting in

[39] https://www.udir.no/kl06/CNC3-01/Hele/Kompetansemaal/etter-vg3

at the R&D department as to learn technical staff work tasks. The company is a world leader within machine tooling and the main area of responsibility for the R&D department is to develop new products and redesign existing products. Due to this, the design of the experiment has two aims: Firstly, to educate future skilled CNC machine operators into competencies on creativity in innovation processes to prepare them to contribute to effective realization of product innovations into new products to the customer. Secondly, an indirect aim is in the long run, to develop technical staff's competencies on collaborating with the production department as to reduce the time to marked for new product innovations.

Time to market for new products depends, among other things on the collaboration between the R&D- and production department. It has been a recurring issue that technical staff do not involve the operators in their creative group processes where new ideas arise or in the development of the technical specification of manufacturing test products. The consequence is a back and forth process between the departments caused by the production department's input on machining requirements for the product to be fully realized. For years machining operators have asked for a closer dialogue between R&D. The technical staff on R&D has not been reluctant but have no practice in cross-departmental collaboration. Further, the initiative among the skilled operators to enter a closer dialogue with R&D have varied due to years of experience and product knowledge, not all being comfortable in this cross-professional dialogue. For plant management and production management this lack of cross-departmental collaboration is not perceived as bad will but rather a result of preconceived perceptions of professional roles, work task responsibilities and educational background.

At present two CNC machining apprentices have finished their three-month stay in the R&D department and one more will start during the winter of 2019. The apprentices' workplace trainer has been the same person as they have during their entire apprenticeship period. The apprentices, who up to this point in their training had worked in the product production department only, have as R&D-apprentices performed some of the work tasks which typically define the importance of closer dialogue between production and R&D. One example is to handle orders from the technical staff on needs for pilot testing, then to produce and test pilot products. When the pilot product is produced and tested technical staff evaluate the results. In this evaluation process there are great benefits from closer dialogue between technical staff and CNC-machining operators, a benefit who was one of the company's argument for why CNC-machining operators must gain training in advocating their knowledge towards R&D. The other way around, the apprentices have also run vibration stress tests of product parts developed by technical staff. Finally, the apprentices have also participated in setting up product-demonstration events for customers, where they have gained training in meeting customers and explain the functioning of the company's range of products.

Discussion of findings

This chapter presents the preliminary findings from the ongoing experiments and discuss how the findings relate to the research question of how lower secondary schools or vocational schools can collaborate with industrial companies as to motivate young people to become vocational workers who are educated in the technical and generic skills needed for future manufacturing industries. We organize our discussion by analysing case 1 and 2 together as these cases demonstrate innovative workplace-school collaborations. Case 3, on the other hand relates specifically to why and how apprentices learning curriculum can be changed as to include skills related to innovation and knowledge on the company's value chain, as pointed out by Solem et al (2016), and how such competence development can be organised within an apprentice's learning contract with a company.

Motivation to make informed career choices

Drawing on case 1, the students in lower secondary school express great enthusiasm over this innovative way of working. As the experiment is organized as a learning activity in the optional subject called "work life science" it is likely that the pupils' preferences are towards vocational education as opposed to an academic degree.

The lower secondary school pupils, as well as the vocational students, express that they are motivated by producing a physical object (a raft) and that they enjoy practical work. The teacher reports that during these weeks where the experiments have been ongoing, he has observed that the pupils find school more meaningful. He finds that the pupils have become more motivated for putting an extra effort into compulsory subjects like mathematics and natural sciences, and the level of school absence has decreased. In our interviews with the pupils three, out of four, say that they will apply for a vocational education. We cannot conclude that this is a direct result of the project. However, the following quotes from focus group interviews with the pupils demonstrate that the project's design of collaboration with a company and vocational students have generated motivation and knowledge on complex problem solving as a collaborative effort:

> *"It was cool to receive the 3D-construction drawings from the company. Then we could really envision how nice our raft could be, and it motivated us [to continue the project]".*
>
> *"The vocational education students questioned us on whether the raft would float and showed us how we could calculate the flotational force of the pipe construction."*
>
> *"It was fun, and I got a feeling of mastering [a complex task]".*
>
> *"To use mathematical calculations when solving practical problems is much more motivating [than learning theoretical mathematics]. It is fun to calculate something [a physical object] you can visually see. It turns out that we did use mathematics all the time [in this raft construction task]".*

The pupils in the vocational school, on the other hand, express that they have enjoyed mentoring the pupils and contributing to the production of parts used in the final raft construction. They report learning gained from having to provide arguments and knowledge to the pupils on which materials are the most suitable for the raft to float well, and which machines are the best ones to use in producing various parts of the raft. Thus, we find that they have learned key elements in communication and collaboration. The following quotes from some of the vocational students exemplifies how they have increased their communicative and collaborative skills: *"we have learned to be patience and solve problems when they arise", "we must simplify the message [when explaining things to them", "I believe we have motivated them to apply for vocational education",* and *"we have learned that we can solve problems together [across the school-levels]*".

Both the lower secondary school pupils and the vocational students report that they have spent a lot of time outside school of thinking about how to make the best raft. Consequently, several pupils and students say they have brought parts from home (for instance parts from a bicycle, from a lawn mower, or an old chain saw) in order to construct an effective motor on the raft. Putting an extra effort into the project indicate motivation and a will of taking responsibility for getting the task done.

The research question in our paper relates to how workplace-school collaboration can motivate young people to become vocational workers. As discussed in chapter 2 there is much evidence that workplace learning is a key variable in developing skills relevant for working life. Drawing on case 2, situated learning of power-electric skills" we now discuss in what way vocational education students' motivation for their career choice has developed further due to workplace learning.

Our key finding from this experiment is that the students found the linkage between learning at school and workplace learning to be at the core of getting to understand the complexity of the job operations involved in the company's production of power distribution switchboards. Included in the learning were the skills of handling modern equipment. The following quotes from students illustrate this learning:

> *"We got knowledge on the Switchboard mounting training as it is in real working life. I liked that the task started with the switchboard, as we do it in school, [but ended with a switchboard control centre unit]. It would have been nice, however, if we had some more time to work on the 3D-documentation drawings, and more time to finish our work properly".*
> *" We were allowed to work with a lot of modern equipment and tools".*
>
> *"The work task was very relevant and authentic for us in second year at school. The task was also well designed as it included the process of which materials and tools to use, and unit function test and quality control of the product in the end".*

Baartman et al's (2018) study of what types of knowledge VET-students learn and how they integrate these different types of knowledge shows that students recognize the importance of vocational knowledge learned in school-based learning environments while they are in the workplace and vice versa, and continuously contextualize knowledge to make it applicable for new circumstances. They also find that students learn differently at school due to their experiences in the workplace. Our findings are in line with Baartman et al's (2017) conclusions. The students' highlight authenticity of the work task and the tools used, exemplified for instance with the statement *" (...) liked that the task started with the switchboard, as we do it in school".*

However, we also find that the students expect some standards of the company instructors involved in the workplace training. The following quotes illustrates this:

> *"I liked the guided tour, but the workers who guided us could have explained to us in a better way, the function of the various parts and products. This have made it easier for us to understand the production line".*
>
> *"The section where the trainers explained to us the various nuts and mechanical wheels was not very well organized (...) and we were not given good enough explanation on how to use the torque wrench. This made us end up bending the first four nuts before we got it right".*

Here, the students provide the company with valuable learning on how to design collaborative teaching activities together with vocational schools. They express the necessity of instructors having pedagogical skills and to have profound knowledge on the technicalities of products and equipment. When the company received this feedback from the students, the company decided to rethink their company-based instructor education. At present they are in the process of giving the instructors state-of-art knowledge on the complexity of the products. We find that, in the encounter with students, whose aim was to learn in authentic environments, this may generate new learning for the company as well. Thus, innovative workplace-school collaboration may trigger innovations both ways.

Halvorsrud (2017) has done a review of extant research on student dropout in Norway. Markussen (2010 in Halvorsrud 2017) has identified five categories of dropout measures that have been prioritized in Norwegian policymaking, one being elements of practice in VET, and a second being to improve the competence level of key actors working around and for the students. We will argue that this experiment and the pupils' self-reported experiences demonstrate a learning in what NOU (20114:7) refer to as broader competencies like learning to learn, critical problem solving and skills in communication and collaboration, but also the trade-specific skills as highlighted by Solem et al (2016). Further, these findings support that workplace-school collaboration for young people can contribute to the development of their inner motivation. Pylväs et al (2017) find in their work that internal motivation is related to the interest in the field of vocation, willingness to learn and interest in the development of expertise, as well as initiative and positive attitude. Findings from the experiments prove that this way of working has provided the participating youngsters with an opportunity to not become "hopeful reactors" Vaughan et al (2006; Chan 2013) but developed their capacity to make informed career choices.

Merging competence requirement for future industrial excellence

Ravn and Øyum (2018) argue that, in new industrial models, traditional blue-collar work is moving into areas of work previously held solely by salaried staff, and that a merging of work content will cause a process of identity-mergers. From the competence requirements discussed in chapter 2 and demonstrated in the discussion of findings related to case 1 and 2 above, we may also argue that there is a competence-merger between blue-collar workers on the one hand, and technical staff on the other. As discussed in chapter 2 one of the key competence requirements for skilled workers is knowing how to initiate- and partake innovation processes. Within this context, findings from case 3 and results from the experiment called "blue-collar R&D apprentices" are presented below.

The following quotes from the two apprentices describe their process of learning generic competences by working with R&D innovation processes and -personnel:

> *(...) You get to try so many different things. You quickly learn to become independent. You must to be steady and self-confident to work here. You can't be reluctant of pushing a button, you can't be reluctant of asking for help. You shouldn't be a first-year apprentice, you must know how the machine works before you get here. You also get to learn more about what clients want."*
>
> *"At the R&D department, I can choose to work with the things I need to learn more about. I can ask for tasks that give me more experience. R&D gives me the possibility to achieve standard curricula goals like being creative, being independent, to learn how to handle the unexpected, and learning to plan." (Apprentice)*
>
> *"Some of these people with PhD's only think about designs and concepts, and they're not practical at all. They are the exact opposite of me. But we manage to communicate and cooperate. It's a very good collaboration, it's like having one person that knows everything. They know something I don't, and vice versa. They don't look down on me. (...)*

The findings suggest that the apprentices found working at the R&D department very different from working at the production department, with deviating work content practices. One of the operators at the R&D department were responsible for training and following them up, but the apprentices were soon expected to manage on their own. When working in the production department, they were used to an ordering system always telling them what the next task would be. At the R&D department, however, choosing which tasks to prioritize became more challenging as there were different ways of receiving an order. Orders would be delivered by e-mail or the phone, and sometimes someone would just stop by and ask them to do something. They got the freedom to choose how they wanted to perform their tasks. The ability to self-organize, communicate and make decisions was of crucial importance. The apprentices also got the opportunity to learn how to use new CNC machines, and they got experience in programming. The apprentices say that the work placement at the R&D department has given them the opportunity to develop their creativity and independence and increased their skills in planning their tasks and responding to problems.

It is the R&D department who is responsible for arranging product demonstrations for clients. Both apprentices got to take part in several demonstrations during their work placement, and this experience has increased their understanding in why the products are made the way they are. The following quote from one of the apprentices demonstrate the motivation and learning gained from participating in a meeting with customers, where they performed a product demonstration:

> *"You get a very good comparison. You get to see how big of a difference it makes using something we have made, against something else that's not as good. To see how good that attenuator works… It was like, "why do people buy that other stuff?"*

Seeing the clients' positive reactions to the products have also given the apprentices even more of a professional pride of working at the company. The apprentices' trainer at the R&D department thinks that CNC machining operators may be a productive link between R&D and the production department in the future. However, this will require rather self-confident apprentices with enough practical experience in machining processes. The apprentices' training instructor describes this in the following way:

> *"Some people can find it very frustrating not knowing what they will be doing tomorrow. I think it's exciting. But I'm sure it can be difficult for some people. That's something we can be considerate about. (…) I think it's important that the apprentices that come here have a solid ground to stand on, so they can be quite independent. If not, it could almost be traumatic for them, I think. We demand that they do something, and then they can't do it. The task becomes too big, too difficult."*

If an apprentice with too little experience was chosen to sit in at the R&D department, the tasks would turn out to be too difficult, the trainer states. Consequently, the R&D work placement would become a bad experience as opposed to an opportunity for them to learn and develop their skills. Thus, the trainer thinks that this way of working could be difficult for some people. The apprentices had learned that product innovation processes included a 'try and fail'-method of working, and a key characteristic of the work was that it did not produce immediate tangible results. The workplace-instructor warned that this way of working may reduce the CNC machining apprentices' motivation unless you are prepared about the different nature of producing "nuts and bolts" on the one hand and partaking in product innovation processes on the other. We believe the following quotes from the training instructor gives an illustrative picture of these different natures, and how it plays out for the apprentices:

> *"I think they're learning a lot here. Because now they really must* think. *It's not enough just pressing a button or doing something that's been done 300 times before. Like I said to them, everything we do here is something new. (…) You have to behave like what you're doing is really dangerous, you have to be really attentive. (…) In the production department you get to see the result of your work right away. You don't get that in here. But this is a job too. Somebody wants an answer."*

Sitting in at the R&D department does not automatically give insight into innovation processes. It is decisive that the apprentices themselves are active and ask their colleagues questions. This is in line with Pylväs et al.´s (2017) findings on prerequisites for effective workplace learning for apprentices. She found that to get required support to develop their vocational expertise, apprentices were expected to not only be motivated, self-directed and responsible employees, but also brave enough to ask for help and guidance.

We find it important that the R&D-colleagues include the apprentices as a part of the work processes and share their experiences for the apprentices to become part of the R&D community-of-practice. Julian Orr's work (1997, 2006) on how copier technicians diagnose problems by storytelling may bring us further on suggesting how the work of production innovation processes must emphasize the work as a practice and not as 'tasks' designated to technical staff, and that effective manufacturing processes in the future requires a rethinking of both organisational design and varieties of competences across business functions.

Conclusions and implications for further research

We will draw attention to two findings and perspectives in the work presented in this paper. The first is that in order to ensure enough access to young people who have an inner motivation for becoming skilled expert in future manufacturing work, the lower secondary school-system must be included in what traditionally has been vocational education-workplace collaboration. We have seen that workplace-learning opportunities for young people generate motivation for learning both trade specific and generic competencies and make it easier for young people to make informed career choices. We find additive effects of learning in school(s)-company collaboration in both the lower secondary school, the upper secondary vocational school as well as in the companies. When young people meet across school levels to solve an authentic task, we find that motivation goes both ways: the pupils in 9th grade increase their motivation of vocational education as a career choice due to having learned what vocational students learn and work with. Likewise, the vocational students have developed their competences in communication and collaboration in the role of mentoring the younger ones. These competencies are at the core of generic skill requirements. Finally, the company has gained more insight into which role they can take, as a provider of modern tools and machining, formulating authentic work tasks which the students must solve, and demonstrate the importance of mathematical calculations in core job tasks in the production system.

Secondly, the learning of future skill requirements presupposes that much of the learning must take place as collective processes and dealing with authentic problem solving. Such a prerequisite for young peoples' motivation to become vocational workers challenges the two different systems of private enterprises versus public schools. Obviously, for manufacturing industry learning, development, innovation and production mainly takes place as collective efforts in workgroups. Quite contrary, the school system is organised as to develop the individual student measures by quantifying learning with grades and marks. It seems reasonable to challenge the school system on how they can contribute to developing young workers with the varieties of competences asked for by "factories of the future". Consequently, we must strive for developing new models for young people to present their qualifications, including their motivation and self-confidence. If this becomes a part of schooling in all undergraduate levels, we may get young people who increase their self-confident in seeing themselves as partaking in a rapid change of work characteristics. To institutionalise workplace-school collaboration, with inspiration from the cased discussed in this paper, may be a valid contribution to solve this challenge.

The background for our research has been the contemporary debates over future competencies required in future working life. As discussed in chapter two, the emphasis put on generic competencies like communication, collaboration and ability to take on responsibility for ensuring a task to be done, challenges the curriculum and teaching methods for young learners. The challenge is partly a pedagogical, structural, collaborative and financial challenge one. No matter how the school system and the industries themselves set up innovative collaborative activities, however, there is a need for future work environment research on which capacities these new competencies represent when it comes to organisational design and industrial productivity. Being a skilled worker in modern manufacturing industry means that one holds both technical and social skills and that both dimensions are necessary to operate the complexity of future manufacturing. From this, we will argue that competencies fit well as an inclusion in both the social- and technological dimensions of socio-technical systems design, but research must be done on the mechanisms by which competencies become "inputs" and "outputs" of an STS design. Claussen, Haga and Ravn (2019) argue that there is a need to re-invent an STS position to address contemporary and future organisational realities. Originating from The Tavistock Institute of Human Relations and their studies in coalmines during the 1950's, and developed further in the industrial democracy project in Norway (Emery and Thorsrud 1970) during the 1060's, social-technical systems theory challenged the perception of universal principles and designs of organisations based on specialisation and coordination. Rather, the empirical work on work-processes, tasks, technology and organisation as performed by, among several, Trist and Bamforth (1951), Herbst (1974), and Emery and Thorsrud (1976), suggested simpler organisational designs that allowed the workers' involvement in the working processes by increasing the complexity of the work tasks and not reducing the complexity of the organisation. Within this perspective it seems necessary to include new competence requirements, and even young peoples' expectations of further skill development in work, as a parameter when designing work tasks in future manufacturing industries.

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