"The most important safety device is you!" On the specific nature of high-tech work process knowledge

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This paper deals with the subjective and the collective nature of knowledge as it may develop in high-tech work processes. It argues that high-tech work requires not only skills but also experience of thinking and reflecting these work processes through scientific concepts. This collective quality of *work process knowledge* (Fischer, 2002) is termed "scientification" (Langemeyer, 2012, 2014). In addition, the experience gained by reflecting processes in scientific concepts is seen as paramount to the quality and the safety when using the potentials of high-tech. Therefore, the paper does not aim at detecting in a positivist manner an overall societal tendency that automatically occurs or that would arrive at our working life without contradictions. It starts with an outline of 'high-tech' in working life, then explains the difference between 'scientification' as a matter of collectively developing work process knowledge and 'similar-scientific' practice as a form of practice in which workers lack a scientific comprehension of technological processes. Last but not least, the paper presents and discusses an empirical case study of perfusion-students learning in a simulation-OT, to exemplify how a 'similar-scientific' activity may be the starting point for a collective development of workers knowledge and practice.

Key words: scientification/epistemification of work, work process knowledge, simulation-based learning, developmental work research, co-operative competence

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The general experience that work processes located in high-tech environments require '*knowledge'* has precipitated catch-words such as 'knowledge' and 'information society' (Daniel Bell), 'information age' (Manuel Castells) and the 'knowledge-based economy' (Bob Jessop). 'Knowledge work' is seen as a key to innovative research questions and programmes (cf. Konrad & Schumm, 1999). In the discourse on the competitiveness and viability of nation states to ensure economic growth, 'knowledge' is said to be a new resource and a new productive force for global value chains. These beliefs seem to be highly plausible against the background that, in production as well as services and administration, technologies largely defined as 'intelligent' have been broadly implemented and sometimes demand from users a certain kind of agility and keenness. However, the question is still disputable whether the natural sciences that are used for the invention of technologies demand more scientific knowledge of the workers, so that generalisations with regard to professional knowledge and an assumed 'knowledge work' are justified.

The core argument that this paper develops is that high-tech work requires not only skills but also experience of thinking and collectively focussing on these work processes through scientific concepts. Thus, it highlights the subjective and the collective nature of knowledge as it may develop in high-tech work processes in terms of safer and more purposeful ways of working. This quality of *work process knowledge* (Fischer, 2002) is termed "scientification" (Langemeyer, 2012, 2014). In addition, the experience gained by collectively reflecting processes in scientific concepts is seen as paramount to the quality and the safety when using the potentials of high-tech. Therefore, the paper does not aim at detecting, in a positivist manner, an overall societal tendency (like the assumed 'knowledge society') that automatically occurs, or that would arrive at our working life without contradictions. It starts with an outline of 'high-tech' in working life, then explains the difference between 'scientification' as a matter of collectively developing work process knowledge and 'similar-scientific practice' as a form of practice in which workers lack a scientific comprehension of socio-technological processes. And last but not least, the paper presents and discusses an empirical case study of perfusion-students learning in a simulation-OT to exemplify the theoretical approach developed before.

‘High-tech’

The advance of technology appears to common sense as a process of replacement or crowding out. The analogue telephone is substituted by digital and mobile telephones, the LP-player by the CD-player which is replaced by integrated chips in mobile phones and similar electronic devices with audio functions. Seen from the work processes, this notion of technologisation is however misleading. A new digital technological component does not simply substitute an analogue one; it also establishes new relations to former innovations and brings about new potentials for their uses. What emerges today in many fields of societal practice is a socio-technological complex of actuators, electronics, and sensor systems, in which digital information and communication technologies create new potentials of connectivity, regulation and control (Rammert, 2007). Thus, central dimensions of today’s technological advance are:

1. By means of the interplay between hardware and software, almost infinite possibilities are given to save and process huge amounts of digital data, to multiply, share, analyse, and use it from manifold sites;
2. technological communication between hardware-components (including miniatures such as RFID or nano-chips) can include various aspects of the analogue world (e.g. the use of energy, the logistics of material etc.) that can be processed in (almost) real-time so that
3. automation and robotics can be flexibilised and diversified according to changing aims, needs or purposes and
4. by means of visualisations (i.e.: displays , videos), digital technologies can be used to simulate actions, to collectivize experience, to experiment with, query, control and supervise certain work processes;
5. finally, this level of experimental action possibilities is connectable to real production or work processes.

The most striking advance is however the fact that technology increasingly ‘acts’ as software *agents* that independently search for and retrieve data from different sites that detect automatically errors or patterns, and produce new algorithms according to certain logics ‘discovered’ e.g. to fix the problems, to adapt to changing actions, or to determine new objectives. Thus, decision making becomes increasingly a function of automation. Consequently, possibilities of human intervention seem to become a race against time as algorithms proceed on a digital basis faster than humans. This problem is aptly exemplified if we think of recent turmoil in the stock markets. With an automated trading at the Wall Street stock market in New York, a crash was produced on May 6, 2010. As transactions nowadays take less than 250 micro seconds, not surprisingly, the Dow Jones crash occurred in only few minutes. The astonishing message hereafter was that algorithms also ‘fixed’ it in only another few minutes. However, further analyses of these digital processes for human reflection were completed only six months after this event.

The quality of these technological developments thus seem ambiguous: On the one hand more and more intellectual work processes (e.g. fault finding) can be technologically supported, resolved and accelerated; on the other, especially if quality and safety needs to be ensured, a plethora of potentially relevant and available information increase the significance of workers' comprehension and anticipation abilities. In what follows, the latter development shall be further explored with a special focus on co-operation.

‘Scientification’/’epistemification’ and ‘similar-scientific practice’

The next section deals with these technological developments as a problem of the ‘scientification’ or ‘epistemification’ of work. ‘Epistemification’ signifies a shift in professional life through an augmented influence of expert knowledge on work practices. In relation to the ethnographic field work on trades on financial markets, Karin Knorr Cetina (1999, p. 1) expanded her research on “how we know what we know”. This question was originally guiding her inquiries in the fields of high energy physics and molecular biology. Here, *epistemic cultures* of natural sciences were revealed as differing according to procedures in laboratories, technologies used and documentations developed in the respective field including symbolic and power relations. Knorr Cetina concluded that science is not an autonomous sphere independent from culture and society, but that both would be integral parts of scientific developments. In the subsequent studies on financial markets, she conveyed that we can detect many parallels to laboratories as the reality here is "purposefully assembled and unfolded by professional knowledge workers and whole technological systems which provide the frames of reference and the means for experience and transactions to take place" (Knorr Cetina & Preda, 2001, p.30). Thus, the differentiation between cultures of science ('epistemic cultures') no longer seems important. Rather, with regard to the interaction of different kind of professionals or experts in co-operation, the hybridisation of knowledge came to the fore:

> "But increasingly, there are scientific fields that are not so neatly separated: fields that have multiple stakeholders, more diverse objectives, include interventionist goals, and cannot be exclusively analysed against the backdrop of received philosophical ideals of basic science. Think of synthetic biology, nanoscience, climate science, and even neurophysiology and neuroscience: not to mention most areas of information science and technology. These multi-charged fields are 'too relevant' to societal concerns, human diseases, or questions of economic wellbeing to be left to their own devices and interests. Conversely, many areas of knowledge outside the sciences also include epistemic orientations and components: think of education, music, and even dance, areas that can be better understood if we approach them as knowledge cultures of their own kind. Many domains of practice are now 'scientised': they are expert systems infused with knowledge and information technologies developed through research and practical applications. This is where a particular understanding of epistemic cultures becomes relevant: the notion that they have to be seen as a nexus of lifeworlds, or as merged realms of existence" (Knorr Cetina & Reichmann, 2015).

'Knowledge cultures' are hence distinguished from 'epistemic cultures' as "the general knowledge culture […] provides a sort of scaffolding for epistemic cultures" (Knorr Cetina, 2007, p. 362). The latter "is designed to capture [the] interiorised processes of knowledge creation" and "refers to those sets of practices, arrangements and mechanisms bound together by necessity, affinity and historical coincidence which, in a given area of professional expertise, make up how we know what we know" (p. 363). Conversely, the concept of epistemic cultures mainly captures "micropractices of laboratories and other habits of knowledge practices" (p. 367) while there are larger "knowledge systems" that set up for example "the architecture of observation rules and strategies", the "units that generate and process the observations" (p. 368). Given the contemporary architecture of knowledge systems of financial markets or of the global 'knowledge economy', Knorr Cetina points out that "knowledge" is no longer "a specific commodity in that its value and validity resides in the timeless qualities it discovers in a referent", but that the "information-knowledge" that is economically used "suspends the quest for timeless qualities in favour of the quick identification of time-bound occurrences" (p. 368). Therefore, "knowledge cultures", understood as a certain "cultural organisation" at a wider societal level, "have real political, economic and social effects which are not neutral with respect to social structures and interests or with respect to economic growth" (p. 370).

In their studies on expert cultures and professional development, Monika Nerland and Karen Jensen refer to "epistemification" "to describe the developments in which the general significance of expert knowledge is increasing, as is the prevalence of science-generated knowledge in the organisation of everyday life" (Nerland & Jensen, 2010, p. 85). Their understanding of 'epistemification' highlights "the 'logics of practice' inherent to knowledge production and validation" which "diffuse into other areas in society" (ibid.) and which implies "that traditional boundaries between areas of knowledge production and application are blurred, leading to a hybridisation of forms of knowledge and their related agencies" (ibid.). Especially (yet not exclusively) with regard to these developments, the insights of socio-material approaches have become paramount that "the material is not secondary, but integral to the human", that it is "the being-together of things that actions, including those identified *as* learning, become possible" (Fenwick, Edwards, & Sawchuk, 2011, p. 6). Accordingly, Nerland and Jensen investigate professional development as "object-related", i.e. how "objects and artefacts at disposal for professional practitioners incorporate central features of their knowledge domain and serve to mediate historical and recognised ways of doing professional work" (2010, p. 87).

The discussions of 'knowledge' and 'epistemic cultures' (Knorr Cetina) as well as the role of 'epistemic objects' in professional development (Jensen & Nerland) show two important threads of the topic: first, the practice-turn of social sciences on science and knowledge production including expert cultures and professional development, and second, the analyses of (economic) power relations within the production of knowledge. But there are two more aspects missing.

Similar to the discourse on "epistemification"/"scientification", my approach stresses a societal shift related to the broad use of 'high technologies' as epistemic objects which implies that expertise, competence, and knowledge development lie in new ways of learning and researching *integral* to work or practice. However, within these practices, science is not considered as a domain of knowledge exclusive to experts that is only currently blurred or hybridised. Historically, this would be wrong and misleading. My suggestion is to recognise the incomplete nature of science especially in scientificated work practices. Furthermore, work processes as I scrutinise them are not categorised as scientificated from an objective point of view only; they are looked at in terms of the psychic quality of scientific thinking, from the standpoint of the "knowing worker", as well.

If we consider some insights of the psychologist Lev S. Vygotsky, the concept of "scientification" can be reinterpreted as the reorganisation of someone's entire intellectual behaviour through thinking in scientific concepts. According to Vygotsky, these concepts (and the theories to which they belong) have a subsidiary function in transforming spontaneous ways of thinking and activity into ways that enable purposefulness, exactness, attentiveness, awareness and deliberation (see Vygotksy, 1997, ch. 6). The change is not merely about the application of scientific concepts, and not just an internal psychological one, but rather a transition within the relation between someone's mental activity and someone's practical or social action with others:

> "This transition to a new type of internal perception represents a transition to a higher form of internal mental activity. To perceive something in a different way means to acquire new potentials for acting with respect to it. At the chess board, to see differently is to play differently. By generalising the process of activity itself, I acquire the potential for new relationships with it" (Vygotsky, 1997, ch. 6, section 2).

This idea can be linked to Michael Polanyi's theory. Following his concept of the "tacit dimension", knowledge can be reinterpreted as a form of knowing, as a dimension of practice which is not identical with all the knowledge that we can verbally express and thus dispose of in an objectified form. This is the wisdom impressively articulated in the quote that "[w]e can know more than we can tell" (Polanyi, 1966, p. 4). However, in reaction to an overly objectivistic notion of science, this phrase has been interpreted in a rather dogmatic way: that our practical knowledge is inexplicable and therefore in principle "tacit" or "implicit". Bengt Molander intervenes against this radical conclusion by arguing for an important distinction that

> "on the one hand, all knowledge can be said to be fundamentally tacit, on the other […] no knowledge is completely tacit" (Molander, 2009, p. 55).

He thereby agrees with Polanyi that knowledge should be regarded "primarily as something dynamic and in motion", that it is better comprehended as 'knowing' or as 'knowledge in use'. In relation to this, "'[t]he tacit' is to be found everywhere and nowhere" (p. 57): it is not only part of practical skills such as cycling but also of every act of thinking itself, and consequently in every activity of learning and knowledge creation. The crucial insight is that

> "knowledge as used by human beings does not come divided into 'practical' or 'theoretical'" (p. 55).

The recognition of 'knowing' or 'knowledge in use' is misunderstood if we conclude that with the 'tacit dimension' we are immediately entering the sphere of something completely tacit. If we accept this conclusion, Polanyi's theory would declare the impossibility of relevant empirical research on work and learning. Yet Molander reasons:

> "For people within a practice, what they do is at least as explicit as what they say. And in no way is what they do 'implicit' in what they say" (p. 57).

The problem is better understood if we consider the historical background of a specific notion of science and theoretical knowledge:

> "[T]he terms 'explicit' and 'implicit' introduce a meaningful distinction only within 'the theoretical knowledge tradition'… It is within this idea of theoretical knowledge that we find one of the seeds of that conceptual split

> between subject and object which has become such a dominant feature of Western philosophy and Western science. The human being is the subject who thinks about something else, the object" (p. 57).

It is against this background that we can see "applied knowledge as a separate element" or that we "can have knowledge without knowing how to *apply* it", because we find in this tradition e.g. "the conviction that knowledge *mirrors* or *copies* reality (although with certain distortions)" as well as "the conviction that knowledge can be *formulated* in words and by means of the language of mathematics" (p. 58). It is due to *this* cultural background that we also conceive competence, qualification and skill in an objectified and reified way where "the worker is really reduced to a 'means of transportation'" (p. 61). *What is hidden in this paradigm is not some kind of knowledge, but in fact the 'knowing worker'"* (ibid, my emphasis). Molander therefore suggests the reinterpretation of knowledge as a "form of attentiveness":

> "Attentiveness belongs to the whole human being. It is not purely 'intellectual'. Emotions, attitudes, questions, sensory presence and much more are actually (constitutive) parts of the knowing human being, thus of knowledge. Sometimes the term 'presence' works better than 'attentiveness'. Presence focuses on *being there,* not only sensory presence as openness to various aspects of the world, which in itself requires learning and practice, but as *being* in the world (in practices) *together with* other people" (Molander, 2009, p. 68).

By arguing that scientific concepts and theories *restructure* someone's "subsidiary consciousness" through which someone is capable of drawing attention to certain issues at work including those that are not, or not entirely, given by our spontaneous way of seeing things and by sensual perception, the notion of the "scientification"/"epistemification" gains a new dimension. The capacity to think scientifically is the ability to "look behind or beyond a system of facts or to grasp it as a fabric of indications that point to a latent interrelation, an ability which resembles the capacity used in the process of sensory perception when we make an effort to recognise a diffuse pattern" (Neuweg, 1999, p. 208, my translation). The "scientification of work" thus stands for a different type of social exchange, co-ordination and labour activity which challenges the intellectual side of work to cope with objects and objectives of work that are only partially present as concrete sensual objects. Scientificated ways of working do not emerge when approved and tested scientific knowledge is applied, but when the subjects of work face an increased process-complexity and when objects of work increasingly resemble scientific objects of study. Consequently, their work requires vigilance, a keen mind, learning, researching and reflection during the social construction of these objects through their work. The challenges to scientifically guide and reflect this process cannot be met if we think of professional development only in terms of an individual process. If scientific insights are not collectively shared and developed, and if the significance of scientific concepts to guide the collective work process are not understood, then practice remains delicate, precarious and risky. But as scientific knowledge is not a complete and perfect form of knowledge (like in research), we need to address more precisely the intermediary and intersubjective quality of knowledge that may be termed 'scientific-like' or 'similar-scientific'.

This argument can be further illuminated with regard to the "work process knowledge" which considers a "specific type of knowing, developed by practitioners in order to cope with modern (and very often computerised) work processes" (Fischer, 2002, p. 131). Here, knowledge-in-practice is not only relevant to manage a given task, but also to assess the quality of different processes and to anticipate and prevent disturbances or negative effects. The quality of "awareness" or "presence" to these dimensions of work depends not only on practical or methodical skills to process information but also *on the socially shared strategies to collectively interpret the work process as a whole, and a certain situation with respect to 'what needs to be done'*. The work of an OT-team is a good example for this. Interpretations of *'what needs to be done'* emerge and are embedded in the social relationships between actors in the concrete work process: who takes on a leading role for the concerted action and who is accepted as a leader, who is considered as an expert or as an authority for a certain problem, whose decisions are accepted and whose perspective on the problem at hand takes precedence over other perspectives.

The study of learning in a simulation-OT

Perfusion is a relatively new professional field which emerged in the 1950s as heart surgery further developed from operations on a beating heart to surgery with a temporary cardiac standstill. The invention of the heart-lung-machine was the starting-point for this. This technology required a new kind of professional, skilled within both the technological as well as the medical field. Regarding the complexity of these fields, it is quite astonishing that, in Germany, this profession was not raised to an academic level until 2008 with the launch of a Bachelor's course at the Steinbeis Institute and the Academy for Perfusion in Berlin. To give an overview of the technological field, components of the heart-lung-machine are: various pumps, suction devices, tubes, valves, an oxygenator for the gas exchange within the blood, a cardio-plegia system to bring about the temporary cardiac standstill, a reservoir of solutions and units of stored blood to ensure a certain volume circulating within the body and the heart-lung-machine, a blood filter, and a number of safety devices monitoring the arterial and the venous oxygenic saturation of the blood, the haemoglobin value, the haematocrit, the pH-value, temperature, the activated clotting time (ACT), and the emergence of bubbles. Cardiac controlling elements are concerned with the composition of the gas, the flow rate/fluid speed, the blood volume in the chambers of the heart and the temperature of the body. These elements are nowadays largely run on the basis of computer and sensor technologies which display relevant information on screens. How 'primitive' the heart-lung-machine was in the beginning compared to today, can be exemplified with regard to the mechanic pump oxygenator. An electrical engineer, István Babotai reported on this:

> "Within an almost pure oxygenic medium within a closed steel tub rotated six perforated cylinder of steel immersed in the blood and thus covered with a film of blood. On this surface, enlarged by rotation, took place the gas exchange. Unfortunately, it brought about with its rotating perforating cylinders in the blood very much haemolysis. In addition, often foam development within the oxygenator caused trouble. Against foaming, we invented a special method: a drop of alcohol, injected directly into the blood with a needle at the exit of the oxygenator, reduced immediately the ten-

> sion on the surface. The foam disappeared for a while. When it reoccurred, we injected alcohol again. After a four- or five-hour operation a lot of patients awakened the next day with a headache" (Babotai, 2011, my translation).

For the empirical study of the simulation-based training at the German Heart Institute Berlin, two technologies of the simulation-OT are to be mentioned: above all, a patient-mannequin equipped with a beating heart, called the "Orpheus"-System, as well as the OT-video-camera-system which enables students sitting in a classroom close to the OT to watch their classmates carrying out a scenario of simulation-based training. Microphones and loudspeakers ensure communication between the operating team and the trainer who monitors every scenario from behind a large window. The equipment was otherwise identical with a regular OT for heart surgery.

For the investigation of the simulation-based learning it is also paramount that all participants were students of the perfusionist course. That means that there were no professional surgeons, assistant surgeons, anaesthetists, or perfusionists taking part in the training. Only some of the participants were OT-nurses in their former professional life and therefore quite familiar with the work routines of heart surgery. Several participants had passed some weeks of an internship in clinics, and some were already employed as trainees at a hospital where they were trained on the job to run the heart-lung-machine. On the whole, the scenario on which I report here was enacted by beginners. Methodologically, this implies an advantage. Emergence and forms of development can only be studied when practices are in a process of change. We only gain insights into a form of practice if it has not yet come to perfection, if it occurs as a form that is itself an object of collective developmental activities.

The simulation-based training took place in the second half of the first year of the perfusion-course. The trainer, Frank Merkle, an experienced perfusionist who holds a Diploma in medical-pedagogy, has accomplished an external train-the-trainer course and developed the scenario and conducted the training. The main goal of this training was to learn in his own words: *"The most important safety device is you!"* The task corresponded with the standard-situation that the intra-corporal blood circulation is transmitted to the extra-corporal. The twenty participants of the course were divided into four groups, and within each group each person was assigned to play a certain role within the team. While one team performed the scenario, all others were watching them from a video-screen in the classroom. After each session, the participants reflected together on their experiences in a feedback session and a group discussion together with the trainer. Mutual feedback was enunciated without exceptions in a supportive manner. Here as well as in interviews, which I conducted individually, the trainees found their participation in the scenario helpful and motivating. The videotaping (by two cameras: one hand-held camera and one installed in a corner of the OT) also helped to investigate the verbal and non-verbal team-communication. Most importantly, it provided insight into the "presence" and the "attentiveness" of each participant since it captured not only verbal communication but also quite well people's body language: their sights, their body tension, their concentration, distraction and irritation.

The method

The analysis of the data was based on the ethnographic approach developed for workplace studies (Knoblauch, 2000). Under the assumption that technological systems or environments are only comprehensible in the context of their social usage (p. 163), its videographic method tries to capture all human activities and interactions that belong to the analysed work process (p. 164). It focuses not only on actions as such, but also on the deliberate or unintentional forms by which the participants mutually make relevant actions to each other noticeable (p. 165). Its aim is to discern the role of the social context and the social organisation of practice by analysing the concrete interactions of bodies and material objects (p. 169). The advantage of video-data is that it takes visual and material aspects as well as speech into account without destroying the in-situ action (cf. p. 169). However, the in-situ action is often not self-evident. Further data from interviews or group discussions are paramount and enhance the validity of theoretical interpretations, concepts and conclusions (p. 170). In addition to the video-data from the simulation-OT, the feedback sessions and the group discussions after the training were audiorecorded. Thus the collected data were comprehensive and the quality of the analysis could be scientifically controlled.

Concentration on the task

To start with a general impression of the enacted scenarios in the simulation-OT: to ensure common concentration, noises were deliberately suppressed, eyes were mainly directed towards one's own purview. The surgeon, the assistant surgeon and the nurse, all placed around the operating table, were simultaneously fixing their eyes on the tube system at the beating heart and trying to exchange glances with the team, especially the perfusionist. The anaesthetist watched the displays behind the operating table and the perfusionist sat behind the heart-lung-machine concentrating on the pumps, the displays and the touch screen in front of them. Verbal communication within the team then started with commands and feedbacks, shortly articulated in one-word-sentences to avoid as many additional elements as possible. Thus, messages were almost incomprehensible for outsiders. The surgeon ordered for example: "100 in!" and the perfusionist's feedback echoed: "100 in." The order implied that 100 ml of the solution in the heart-lung-machine should now be pumped into the tube system going towards the heart.

Shared concentration was a fragile thing. As soon as someone lost their attention/tension, behaved 'badly', i.e. not according to one's role, or provoked laughter, shared concentration immediately disappeared. Switching between ironic and serious comments caused irritation.

By giving short and direct feedback whether a specific task has been accomplished and whether the status quo looked alright and by mutually reclaiming such a feedback, the team produces a shared feeling of safety. Sometimes the verbal exchange creates the impression as if the subjects of work disappear behind the technology and become invisible:

> Surgeon (male): *Aorta is shut.*
>
> Perfusionist (female): *Aorta is shut, the flow goes up.*
>
> Surgeon: *Starting plegia…*
>
> Perfusionist: *Plegia's coming.*

Surgeon: *...and blue is on* [the suction device for the blood transport away from the heart, I.L.]

Perfusionist: *Blue is working.*

– Silence –

(First group)

Concerted agency

Although most of the orders are given by the surgeon, every word that maintains the flow of the process matters. Attention is not drawn to the word itself, but communication serves in terms of the "subsidiary consciousness" (Polanyi) as a subsidiary or mediating activity for the concerted agency of the team. If the concerted agency is in progress, communication can, as in the case above, become partially silent.

Bringing the action into flow means that each member of the team needs to comprehend and perceive to a certain degree the scientific interrelations of the work process. For example: one student, who played the role of the surgeon, remarked after the simulation that he was unfamiliar with the different cardioplegia methods (for the standstill of the heart, such as "Calafiore" or "Bretschneider") which is why he was disoriented for a while although the team communication would have allowed unambiguous conclusions for further actions. What is salient here is not that the messages were consequently imprecise or unclear, but that they could not be integrated with other information into the intellectual behaviour (esp. the subsidiary consciousness) that ensures attentiveness to the work process as whole, or to a virulent problem in particular.

It can be, however, that the team comes to terms with the attempt of simply 'muddling through' and that its members mutually confirm themselves in doing so. This can be detected in the following exchanges:

Surgeon (m): Perfusion – everything alright?

Perfusionist (m): I guess so.

[both: head nodding]

–

Surgeon: Everything alright now?

Assistant surgeon (m): Yeah, alright.

Surgeon: O.k. let's go on then.

(Third group)

This behaviour is certainly quite dangerous in real situations, because it brings about a false feeling of safety. Indeed, in that scenario of the third group various problems, unclear to outsiders, occurred at the same time. It was only obvious that the perfusionist had problems with the touch screen module to administer heparin (medication for diluting the blood) and to test the activated clotting time (ACT). The discussion afterwards revealed that simultaneously the patient's blood pressure decreased because a suction device was not working, and the cardioplegia was not administered, contrary to the anaesthetist's announcement, because the assistant surgeon confused two clamps while opening a tube. The most striking deficiency however was that the team failed to pay attention to the patient's artificial respiration while he was connected to the heart-lung-machine.

Despite such obvious deficiencies, it would be unfruitful to infer that the team members had simply a lack of knowledge or practical skills, since every single one of them knew about the significance of the patient's oxygen supply, and the problem was not merely about the functioning of technical devices of the heart-lung-machine or a matter of communication. What was missing was a professional, mutually shared way of thinking how to hold relevant aspects and processes of the operation present in the team so that each member knew *how to organise all the different information into a coherent picture, and to critically examine and correctly prioritise different steps to undertake*. This task requires the critical reorganisation of one's subsidiary consciousness, a development of one's knowing in relation to others'. The capacity to focus on objects in the process of change is a scientific challenge, since awareness to process-complexity needs analytic and not just practical expertise. It is too complex to run it down to a number of rules. The difference in competence can only be explained against the background of the scientification of work.

Scientificated ways of working

Professional ways of thinking are based on the incorporation not only of scientific knowledge in terms of facts, but more precisely in terms of conceptual or theoretical ways of knowing to which the subjects also relate in a self-reflexive way. It is not thinking *of* certain bodies of knowledge but the thinking *within* certain ways of knowing that are crucial. It implies the capacity to critically evaluate one's knowing or knowledge-in-practice in the light of the problems at hand, and to develop mental and/or practical strategies to solve them. The practical difference between scientific and everyday-life knowing can be recognised in Vygotsky's argument that:

> "By generalising the process of activity itself, I acquire the potential for new relationships with it" (Vygotsky, 1997, ch. 6, section 2).

This generalisation is theoretical but not purely abstract or unpractical, because it is not distracted from the subjective and collective practice. It maintains an analytic and self-reflexive relation to the socio-material practices by which subjects collectively generate their knowledge-in-practice. It helps to reorganise one's own intellectual and practical behaviour with regard to certain problems or tasks, then to co-ordinate one's action with others and to take on collectively the responsibility at stake. Without this scientific way of thinking, neither the individual nor the collective would be able to behave adequately within the work process. They could not move mentally from their standpoint within the particular division of labour to the standpoint of someone else or relativise information with respect to the particular context. Consequently, the mutual encouragement of the team devoid of this intellectual dimension of scientific knowing is nothing but deceptive; a similar-scientific practice emerges: Pieces of scientific-like information are taken into the focus of the collective team work, but their significance in that particular situation is misjudged or only partially considered. They only deal with the situation with a slight idea of what could or must be done. Furthermore, the work process knowledge of the team is *not* yet 'distributed'; their actions are noticeable to others, but as far as they are rather invisible and out of focus, the mutual feedback cannot yet ensure that the team integrates relevant aspects of the work process into the form of a general picture, and keeps this in mind while collaborating. Competence development on a collective level therefore needs to start with a reflection on this intermediary quality of similar-scientific knowing and continue with elaborating it collectively. This practical side of the “scientification” of work proceeds on the team’s capacity to arrange and rearrange relevant information, material, and action into a general picture and to evaluate it in a far-sighted manner for enhancing their practice. In many high-tech work processes, this is also the purpose of numerous safety routines. They only serve this purpose when they are linked to scientificated ways of thinking. Nevertheless, this ‘scientification’ has no end; there is no perfection in this coming-to-perfection.

Facets of role play

If everyone in the team loses this general picture, and therefore is unable to steer the concerted agency of the team towards a safer situation, its members will inevitably face a stalemate. This was the case in the following scene. It was nevertheless interesting that, in this situation, the students did not stop acting as a heart surgery team. Whilst awaiting the solution of the problem of the ACT-reading, they acted out their roles in a humorous way. The assistant surgeon began to imitate the small-talk which is occasionally conducted in OTs. Probably, the students had already implicitly learnt the meaning of small-talk, as it serves not only to bridge the void time, but also to resolve a stuck situation and to find a way back to concentration and order.

> Assistant surgeon (m): *How is the ACT?*
>
> Perfusionist (m): *Where is this measured? 100 – could be?*
>
> – Silence –
>
> Anaethetist (m): *Everything’s alright here. [Pause] Let’s continue.*
>
> – No reaction of the perfusionist, no reaction of the team. –
>
> Assistant surgeon [to the surgeon]: *Did you have a nice week-end?*
>
> Surgeon (m): *Yeah, not bad. A bit of cycling [laughing].*
>
> Assistant surgeon: *What’s the matter with the sucker?*

> [Via loudspeakers, the trainer instructs the perfusionist how to handle the touch screen module.]
>
> (Third group)

In this sequence, the perfusionist as well as the surgeon had lost awareness of the work process, the former because his attention was totally absorbed by searching how to set the ACT-measurement on the touch screen, the latter because he had no alternative idea how to manage the situation. Since the surgeon is the person where all the threads of the work process come together, it is he (or in a few cases: she) who acts as a 'conductor' of the co-ordination or the concerted agency. In this case, however, he awaited the feedback of the perfusionist. Whilst the assistant surgeon retreated to a different, more informal level of communication, there was a diversion from the lack of leadership. After the small-talk sequence and the help of the trainer, the student resumed his role as a surgeon.

It is also remarkable that in this rather playful framework the surgeon was recognised, even though this role was played in terms of its professionalism in a poor way, as the highest authority whom no one dared to reproach for certain mistakes. If he was criticised, it was done in a careful, often indirect manner. In contradiction, there seemed to be no taboo for playing a joke on a confused perfusionist:

> Surgeon (m): What's the new ACT?
>
> – Perfusionist (m) is concentrating on the screen, touching it without corresponding to the surgeon. –
>
> Surgeon: O.-k. …
>
> Assistant surgeon: We have an easy-going perfusionist, haven't we?
>
> – Laughter –
>
> Anaethetist (m): An old machinist, isn't he?
>
> – Laughter –
>
> (Third group)

Such contrasts between a more informal, humorous and a rather formal and serious role play show a side of work process knowledge that is not only about the technological, the medical or the communicative aspects of work. It is more generally an "understanding of work roles in parts of the organisation, other than the employee's own, an awareness of the interdependency of the activities in different departments, including the characteristics of the system as a whole" (Griffith & Guile, 2003, p. 61). But this knowing is misunderstood if we interpret it as a neutral or merely rational way of knowing. It is at the same time a way of 'attuning' oneself to the social power relations to which this understanding and this awareness socially belongs. As we can learn from the last sequences of the simulated scenario, this 'attuning' should not be identified with adaptation only; it may include an ironic attitude towards certain authorities as well as strategies how to play with or negotiate expectations that are linked to a certain role. In relation to this, the dimension of implicit learning in each learning process comprises not only internalising bodies of knowledge but also, within certain variations, the existing role models to which certain responsibilities and competences are socially attached. The enactment of roles is the form by which work process knowledge is framed. The significance of roles and role models therefore needs to be illuminated some more.

First of all, since perfusionists are recruited from the non-academic staff in the German health care sector, it is important that they identify with a more responsible and intellectual role. Hence situations might occur where a certain danger, a problem or the solution to a particular problem is conceivable from the perfusionist's perspective only, and would be missed, for example, from the surgeon's point of view. Therefore perfusionists must be ready to lead the team in difficult situations. This indicates that leadership in surgery is not important *per se*. In other words, it is not important that someone leads regardless of the concrete challenge to master. It is important that the team does not comply with structures of formal authority but that each team member is capable to generate leadership legitimately with respect to the problem to be solved.

Secondly, since established professional roles must be seen as a recognised schema of work process knowledge framing, sometimes a good imitation of a professional role model is taken as a sign of competence, or a mismatch as a sign of incompetence. Since professions are also a matter of class and gender, role models and its ways of knowing cannot be investigated independently from this. The surgeon is a good example for a professional role that is very often chosen by males and surgery has become (at least in Germany) a masculine domain of work. Connected to this, it is important to recognise that notions of professionalism are often fuelled with a gendered view on the respective work, and correspondingly, particular role behaviour may serve as an ideal to develop professionalism.

Gender relations

By chance, the simulation-based training allowed a comparison of a purely male, purely female and a mixed team. This showed that male students were more inclined to 'compensate' or cover up a lack of competence by a stereotyped role play. In other words, they tended to play their roles with a clear reference to a male habitus (sometimes hard to capture in the transcript): a decisive tone in the voice, a gesture of dominance, sometimes combined with a self-ironic attitude, but clearly conveying that respect and obedience from the team is expected. In the position of the surgeon, some male students even allowed themselves to play jokes on others or to speak rudely to them, especially with regard to female students or to the OT-nurse even though this role was played by a male student. Among female students, this kind of framing of their actions was not obvious. They used polite forms of speech deploying questions rather than orders or added "please" to it. Three exemplary scenes:

> The male team
>
> Surgeon: Anaesthesia, heparin!
>
> Anaethetist: Heparin's coming. – Heparin's administered.
>
> Surgeon: Fine. – Perfusion, everything's o.k.?
>
> Perfusionist: I guess so. [Both: head nodding]
>
> Surgeon: Start up artery.
>
> Anaethetist: Start up artery.
>
> Surgeon: Stop. – 100 in.
>
> Perfusionist: 100 in.

Surgeon: Pressure o.k.?

Assistant surgeon: Clamp please [incomprehensible] [laughter]

Anaesthetist: What was that?

Surgeon: Nurse, I need a new suction device!

(Third group)

The mixed team

Surgeon (m): O.k. we loosen. – Now, make a test!

Perfusionist (f): Does that fit now?

Surgeon: Test, you know that? – O.k., test alright?

Perfusionist: Yeah.
Surgeon: O.k. – Venous! … alright, let's go on the machine. Start slowly!

(First group)

The female team

Surgeon: Heparin in, please.

Anaesthetist: Heparin's in.

Surgeon: Perfusion?

Perfusionist: Yes?

Surgeon: We are connecting.

Perfusionist: Yes, do I have to pump in or not?

Surgeon: Well, yes.

Perfusionist: Then I pump in a little. Is that enough?

Surgeon: Wait a second. – I'll try it in another way [changing something about the tubes]. – Move forward, please.

Perfusionist: Yes, the machine's pumping. – Is it coming?

Surgeon: Yes, yes, fine, stop, thank you.

Perfusionist: O.k.

(Fourth group)

Framing of objects, actions, and work process knowledge

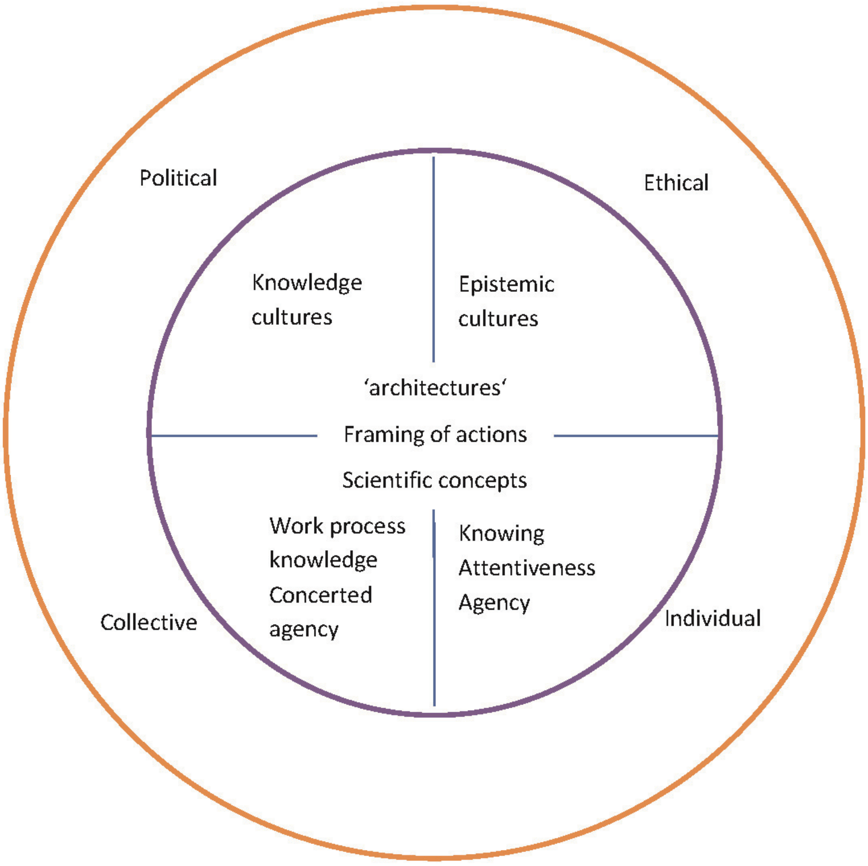
There is certainly not just one lesson to learn from such a comparison, but one seems quite important: With regard to knowledge-in-practice, the specific framing of actions indicated to others can limit or expand possibilities of a team to deal with a concrete situation. The framing of actions indicates, to each member of a team, a certain order and a certain way of perceiving things. It makes solutions of a certain kind more likely than others. As we can observe in the sequences above, the enacted role model of the male surgeon stresses leadership in terms of an expectation of obedience much more than the female role model and thus sets the premise for other team members either to fend off the way of being addressed or to avoid a conflict. If practitioners aim at improving their form of 'presence' and 'attentiveness', their learning process may therefore imply critical reflections on the ways roles are enacted at work, how much energy is absorbed by solving a concrete problem and how much is diverted into more symbolic actions. Whilst the horizon of learning processes for knowledge-in-practice will be widened, the greatest challenge can be how teams overcome a culture of showing-off and blaming, and how to diminish a widespread fear of being criticised.

Conclusion

"Scientification" is a key concept in high-tech work processes to address a certain subjective, and especially a certain collective, quality of work practice. This quality does not automatically stem from the implementation of 'high'- technologies or from the bountiful pieces of scientific information provided by electronic safety elements for example. Instead, as the following figure shall clarify, it needs to be understood as a fragile process with four dimensions of practice vulnerable to contradictions and tensions.

Following Knorr Cetina, the wider socio-cultural level of *knowledge cultures* addresses socio-political decisions e.g. on the division of labour and responsibilities that influence what kind of teams and structures of co-operation are built, or on investments in research and development that effect what kind of technologies determine further investments, engagements and

Figure 1: Four dimensions of the scientification/epistemification of work



work place environments. *Epistemic cultures* are more specific to micro-practices how a team makes for themselves a field or a work place environment knowledgeable. In Knorr Cetina's work this is mainly a question of socio-material practice. But this is not the whole story, as my empirical case study shows. It is important to address the socio-psychological dimension of scientificated ways of knowing as well. Only, if we understand the intermediary quality of similar-scientific ways of thinking, attentiveness and coordination and the collective task to develop scientificated ways of working, we may understand that the scientification of work is not a societal tendency which inevitably takes place. If there is a lack of time and space to collectively reflect work experiences and develop work activities with respect to standard as well as critical situations, it remains a precarious and contested project. In the long run, interpersonal and intrapersonal conflicts are almost inevitable; they make psychic processes more exhaustive and thus errors at work more likely. The struggle for possibilities of collective reflection and co-operative competence development has therefore become one of the core challenges of creating a safer and more sustainable high-tech world.

References

Babotai, I. (2011). Ein Ingenieur auf der Herzchirurgie. Ein persönlicher Rückblick auf die Ära Senning. http://www.usz.ch/SiteCollectionDocuments/Dossiers/50JahreHerzchirurgie/50jhbabotai.pdf

Dieckmann, P., Reddersen, S., Wehner, T., & Rall, M. (2006). Prospective memory failures as an unexplored threat to patient safety: Results from a pilot study using patient simulators to investigate the missed execution of intentions. *Ergonomics,* 49 (5-6), 526-543.

Fenwick, T., Edwards, R., & Sawchuk, P. (2011). *Emerging approaches to educational research: Tracing the sociomaterial.* London: Routledge.

Fischer, M. (2002). Work experience. In N. Boreham, R. Samurçay, & M. Fischer (Eds.), *Work process knowledge* (pp. 119-133). London, New York: Routledge.

Fischer, M., Boreham, N., & Nyhan, B. (Eds.) (2004). *European perspectives on learning at work: The acquisition of work process knowledge.* Cedefop Reference Series; 56.

Griffith, T., & Guile, D. (2003). A connective model of learning: The implications for work process knowledge. *European Educational Research Journal,* 2(1), 56-73.

Knoblauch, H. (2000). Workplace Studies und Video. Zur Entwicklung der Ethnographie von Technologie und Arbeit. In I. Götz & A. Wittel (Eds.), *Arbeitskulturen im Umbruch. Zur Ethnographie von Arbeit und Organisation* (pp. 159-173). Münster, New York, München, Berlin: Waxmann.

Knorr Cetina, K. (1999): *Epistemic cultures: How the sciences make knowledge.* Cambridge, MA: Harvard University Press.

Knorr Cetina, K. (2007): Culture in global knowledge societies: Knowledge cultures and epistemic cultures. *Interdisciplinary Science Reviews*, 32(4), 361-375.

Knorr Cetina, K., & Preda, A. (2001). The epistemization of economic transactions. *Current Sociology,* 49(4), 27-44.

Knorr Cetina, K., & Reichmann, W. (2015). Professional epistemic cultures. In I. Langemeyer, M. Fischer, & M. Pfadenhauer (Eds.), *Epistemic and learning cultures – woher und wohin sich Universitäten entwickeln*. Juventa.

Konrad, W., & Schumm, W. (Eds.) (1999). *Wissen und Arbeit. Neue Konturen von Wissensarbeit.* Münster: Westfälisches Dampfboot

Langemeyer, I. (2012). Socio-technological changes of learning conditions. In N. Seel (Ed.), *Encyclopedia of the sciences of learning* (pp. 3144-3147). New York, Heidelberg: Springer Science + Business Media.

Langemeyer, I. (2014). Theory and practice. In T. Teo (Ed.), *Encyclopedia of critical psychology.* New York, Heidelberg: Springer Science + Business Media.

Molander, B. (2009). What is hidden and what is not? In A. Bolder & R. Dobischat (Eds.), *Eigen-Sinn und Widerstand. Kritische Beiträge zum Kompetenzentwicklungsdiskurs* (pp. 54-69). Wiesbaden: VS Verlag.

Nerland, M., & Jensen, K. (2010). Objectual practice and learning in professional work. In S. Billett (Ed.), *Learning through practice: models, traditions, orientations and approaches* (pp. 82-103). Heidelberg, London, New York: Springer.

Nerland, M., & Jensen, K. (2012). Epistemic practices and object relations in professional work. *Journal of Education and Work,* 25(1), 101-120.

Neuweg, G. H. (1999). *Könnerschaft und implizites Wissen. Zur lehr- und lerntheoretischen Bedeutung der Erkenntnis- und Wissenstheorie Michael Polanyis.* Münster: Waxmann.

Polanyi, M. (1966). *The tacit dimension.* The Garden City, New York: Doubleday & Company.

Rammert, W. (2007). *Technik – Handeln – Wissen. Zu einer pragmatischen Technik- und Sozialtheorie.* Wiesbaden: VS Verlag.

Vygotsky, L.S. (1997). Thinking and speaking. Available online: http://www.marxists.org/archive/vygotsky/works/words/index.htm

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