



Enhancing learning as theoretical thinking in robotic surgery

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Abstract

Professionals in many domains need to deal with increasingly complex, technology-mediated and uncertain work. Thus ways of learning that continuously and flexibly create new knowledge are needed at work. The aim of this article is to describe the logic of theoretical-genetic generalisation, and to use this, in addition to other methodological resources from pragmatism and cultural-historical psychology, for developing a learning method for robotic surgery. In theoretical generalisation, or theoretical thinking, the learner orientates him-/herself in two directions: towards producing general, abstract understanding of dynamic interrelations within a phenomenon, and towards flexibly tailoring good solutions for each particular situation. Based on our ongoing study of robotic surgery, we sketch three different designs for learning which are all based on video-supported joint reflection of real robotic surgical operations. We outline the necessary principles and steps of the method in this context, and finally, discuss the potential of the outlined method for learning.

Keywords: activity theory, developmental instruction, orientation basis, professional learning, robotic surgery, theoretical-genetic generalisation

Introduction

The need for customised products, and new technology's continued penetration into work and life set a context in which change rather than the stability of work is the norm, and in which skills, competencies and work processes are constantly changed or re-valued (Boud, Cressey & Docherty, 2006). Boud et al. (2006) argue about a shift of emphasis from the 'organisational learning' of the 1990s to 'productive reflection', in which the key need is to manage complexity and ambiguity, and learning is contextualised at the workplace rather than merely defined in formal strategies. A societal shift towards 'high technologies' implies that expertise, competence and knowledge development ground learning in new integral ways to work or practice (Langemeyer, 2014). These new ways of learning mean not only that the significance of expert knowledge is increasing, but also that science, embedded in artefacts and practices of work, reorganises, through new scientific concepts, the knowing worker's entire intellectual behaviour.

Learning, in which new knowledge is continuously and flexibly created, is, we assume, increasingly required. The aim of our ongoing research project 'Interpretive work: Developing new forms of work-based learning for the age of digitalisation' (Wahlström, Norros, Seppänen, Schaupp & Toiviainen, 2014) is to make sense, by using and combining various methodological resources, of the new forms of learning that are needed in complex high technology work. For this purpose, we use the notion of interpretive practice, originating from Peircean philosophy and later elaborated by Norros and her colleagues (Norros, 2017; Norros, Savioja & Koskinen, 2015). An interpretive way of working means questioning the observed phenomena, discussing with the team, anticipating the system state, and using various information sources. We have carried out developmental interventions using a methodology of self-confrontations elaborated in French cultural-historical psychology (Clot, 2011; Kloetzer, 2012; Kloetzer, Clot & Quillerou-Grivot, 2015). Self-confrontations serve our purpose by making professionals face multiple viewpoints of their activity, giving birth to new dialogical objects which may turn into new 'theoretical' objects of thinking that have the potential for transforming material objects or organisational activities (Seppänen, Kloetzer, Riikonen & Wahlström, 2016).

Another aim of our research project is to sketch a method for learning interpretive or theoretically informed ways of working. Our argument is that learning can be enhanced through a methodology of self-confrontations, but still needs a method of instruction to organisationally and institutionally support it. A promising method is developmental instruction, based on the notion of theoretical-genetic generalisation, as elaborated by Davydov (1990, 2008) and inspired by the works of Ilyenkov (1982, 2007). Further, the Davydovian theory of developmental instruction was taken into use and elaborated by the community

of Developmental Work Research (Engeström, 1987, 1994). Theoretical-genetic generalisation, or theoretical thinking for simplicity, refers to the identification of the 'genetic' origins of phenomena. A phenomenon's functional relationship is looked for when the parts of the relationship may be completely different, but still dialectically and functionally interdependent (Sannino, 2011, p. 586). Modelling, practical transformation and experimentation are at the root of theoretical thinking, emphasising its processual, practical and method-like character. Theoretical thinking enables practitioners to look for generating mechanisms behind the problematic phenomena they face in their work, which helps them not only to find renewed solutions to emerging dysfunctions or anomalies, but also to build systemic, dynamic and 'abstract' knowledge about the phenomenon in question. The interpretive way of working, and the methodologies of self-confrontation and theoretical thinking share the common focus of enhancing participants' learning of new processes and methods of more theoretical and contentful thinking and production of knowledge.

Our aim in this article is to discover, by following the processual logic of theoretical thinking, the ingredients of the process, and a method for promoting and learning theoretical thinking in complex and technology-mediated work that requires addressing and resolving uncertain issues. We will apply the above mentioned theoretical ingredients to an empirical research case, oncological robotic surgery. The theoretical investigation and the method generation of this article is rooted to ethnographic studies and task-analyses that we have conducted on robotic surgery (Wahlström, Seppänen, Norros, Aaltonen & Riikonen, submitted).

In this article we first take a look at the theory of theoretical generalisation, together with its principle of ascending from the abstract to the concrete and modifications (next section on *Forms of generalizing in thinking and learning*). Second, we describe the main contents of the work activity in question, oncological robotic surgery, after which we sketch three designs for learning, based on our previous work in this domain. These designs vary greatly, ranging from small local learning events to possible large-scale research projects. Later, the section *Steps of learning theoretical thinking in robotic surgery* applies the principles that are needed in all designs if they are to be both practically and theoretically useful. At the end, we discuss the potentials of enhancing theoretical thinking in robotic surgery.

Forms of generalising in thinking and learning

Humans use different kinds of generalised representations of reality as a way of knowing and learning about things in the world. These representations can be internal and mental or external and in some material form. These representations are produced through specific actions of abstracting and generalising, and

once created, they can be used as instruments of similar kinds of thinking and learning actions in various contexts. There are, however, two fundamentally different forms of abstracting and generalising (Davydov, 1990; Ilyenkov, 1982).

Empirical abstraction is a central form of our everyday thinking. It is based on the comparison and classification of objects and phenomena according to their externally identifiable characteristics and common nominators. The connection between things classified through empirical abstraction is formal, which means that no concrete relationship necessarily exists between these things within any real-life system. Generalisation through comparing and identifying similarities also produces an endless amount of different classifications. For example eggs and golf balls fall into the common category of white and round objects, but just by changing the basis of the classification golf balls might be categorized as 'sports equipment' and eggs as 'groceries' or from yet another perspective as 'reproductive cells'.

Instead of categorising of things on the basis of their observable characteristics, theoretical generalisation (or theoretical thinking) is oriented towards examining objects and phenomena as systems of functional relationships and interdependencies. Here, a golf ball is a part of a system that in addition to other golf equipment consists of players, fields, rules of the game, golf clubs and associations, and so forth, that in their mutual interactions form the activity of golf playing. This system of relationships gives its parts a real meaning of existence and invests them with various characteristics that they would not have outside the system. Thus, theoretical generalising does not strive to find universal and eternal definitions of 'things as such', as separate unrelated entities, but to explain things in their systemic contexts through identifying their genetic origins. This also makes it possible to explain why very multifaceted, externally different and even seemingly contradictory things can be a part of the same system, and to investigate the essence that keeps these complex systems together.

Ilyenkov (1982, chapter 3) explains theoretical thinking as follows: '[t]o comprehend a phenomenon means to establish its place and role in the concrete system of interacting phenomena... ..and to find out precisely those traits which make it possible for the phenomenon to play this role in the whole.' To realise this, it is not necessary to make comparisons within a large group of similar phenomena, but to 'study at least one typical case of a living dialectically developed system of internally interacting objective phenomena.' Because of their inherently systemic nature, theoretical generalisations exist primarily as methods, models or concepts that reproduce the core relations that should be scrutinised to understand the phenomenon that the generalisation denotes. Next we will explain how theoretical thinking proceeds and how it is learnt by presenting the principle that crystallises the process of theoretical thinking, the principle of ascending from the abstract to the concrete.

Steps in learning theoretical thinking and the principle of ascending from abstract to concrete

Ilyenkov (2007, p. 19–22) describes one of Pavlov's experiments, in which a trained dog loses its mind when presented with a combination of the stimuli that it had been taught that required conflicting responses. The dog was unable to cope with such a contradictory situation. For humans, on the contrary, this kind of situation and appearance of contradiction is a signal, a potential cognitive conflict, that activates thinking. It is also a point, at which formal categories, 'it is either this or that', no longer serve as instruments for thinking and solving the task at hand, as the contradiction is by nature a paradox; 'A' and 'not-A' at the same time. Encountering this kind of a contradiction may prompt a person to investigate the object more deeply and orient towards explaining something that is yet unknown, towards new concepts and methods of acting, and this calls specifically for theoretical thinking.

Theoretical thinking is an important part of all human activity, but it is especially necessary in work activities that require deep expertise and action on very complex, problematic and systemic objects, as in oncological surgeons' robot-mediated work. The mastery of these kinds of work objects can be supported with theoretical abstraction which, as Sannino (2011, p. 586) argues, 'allows one to generate and project complex, theoretically mastered concrete manifestations and developmental forms of the reality under scrutiny'.

The concept of contradiction is a central notion in the principle of ascending from the abstract to the concrete, which Davydov (1990, 2008) has elaborated as the method for learning theoretical thinking in primary school instruction and curricula. The central idea is that in order to assimilate a new way of acting, it is necessary to become acquainted with how those questions arose for the person who was the first to solve such tasks. As Ilyenkov (2007, p. 17) argues, in order to learn to think theoretically it is necessary to learn the ability to ask the questions correctly. In addition, the principle of ascending from the abstract to the concrete emphasises the importance of creating theoretical concepts and models that help practitioners in various work contexts solve problematic and contradictory situations in the course of their work.

Models that especially support theoretical generalisation 'are a particular kind of abstraction, where the visually perceived and represented connections and relations of the material or semiotic elements reinforce the essential relations of the object' (Davydov, 2008, p. 95). They may be simple prototypes, algorithms or system models that consider the interplay of several different relationships within the same object or phenomenon, or in the form of a 'germ cell' model. A germ cell crystallises the way of dealing with a contradiction that is constantly present within an activity, a contradiction that motivates learning and development as it can be managed in different ways but never ultimately washed away. In oncological surgery, this type of constantly present contradic-

tion exists between removing (cancerous) and saving (healthy) tissue at the same time.

In other words, a learning method that strives to activate theoretical thinking should on the one hand support the learner's ability to observe, formulate and analyse the motivational conflicts that unveil a logical contradiction within their activity, and on the other hand to find a way to manage it through concrete examination of the object, by thoroughly studying some carefully chosen observations (Davydov, 2008, p. 131; Ilyenkov, 2007, p. 21). In our data, the situations named most critical by the surgeons were also situations of a contradictory nature. The contradiction arose from the conflicting goals of removing all the cancerous tissue while at the same time doing it as little invasively as possible to enhance the patient's recovery and retain as normal states and functioning of the operated area. In the videos of the surgeons' robotic operations, this contradiction manifested itself as hesitation, slowing movements, stopping to think or making explorative movements to gain more information. In some cases, this contradiction is more easily mastered than in others, but it nevertheless generates a recurrent learning problem in surgeon's activity and calls for theoretical thinking.

Engeström (1994), based on the formulations of Davydov, has operationalized the process of ascending from the abstract to the concrete in six steps of developmental instruction, each demanding specific learning actions. The first step is the *arousing motivation* through identifying a cognitive conflict that cannot be solved through concepts that the learner already possesses. The second step is *orientation*, that is, forming a preliminary hypothesis, 'an orientation basis', which helps the learner structure and model the knowledge needed for solving the problem and link together the essential points of concern. The orientation basis is a first hypothesis, a preliminary model, in the process of constructing a functional general abstraction of the phenomenon. The third step is *internalisation*, which means enriching the preliminary model by incorporating new knowledge into it while at the same time studying how accurately the model structures and explains the object of learning and organises its parts and details. Through this process, some parts of the explanatory model gradually transform into the learners' internal model. The fourth step is *externalisation*, which means using the created model as a tool for solving concrete problems within a (work) activity. The fifth step is *critique*; in other words, critical evaluation of the validity and usefulness of the model based on the experience of its use. The sixth step is *control*, when the learner stops to analyse his or her own learning and performance in the light of the new model, and corrects the model when necessary. The learner also evaluates the learning method (Engeström, 1994, p. 32-33). The process has been widely applied in Developmental Work Research interventions (e.g. Engeström, Nummijoki & Sannino, 2012; Virkunen & Ahonen, 2011). As the basis of developmental instruction lies in the

specific content of the activity or work in question (Davydov, 2008, p. 120), we will next examine the contents of robotic surgery.

Oncological robotic surgery

Technological advances in optics, digital video equipment, computers and robotics have opened up new possibilities in surgery. A robotic surgery device called the da Vinci Surgical System was first introduced in 2000. Since then it has become the dominant device in the field. The robotic-assisted operation is performed via tubes (trocars) inserted into the patient through small incisions. With the sophisticated technology incorporated in the robot, a surgeon can tele-operate the instruments in the human body with the subtlety of a human wrist. The popularity of robot-assisted surgery, with its 'minimally invasive' technique, can be attributed to the novel means it offers to the managing of the central contradiction in oncological surgery, removing the cancer as carefully as possible, while doing minimal damage to the body and its life functions.

Most importantly, robots offer better visualisation than other technologies. A specialised stereo endoscopic lens and camera provide the surgeon with a three-dimensional view of the field under operation (Su & Smith, 2012). As palpation, that is, touching and concretely feeling the body of the patient, are essential in open surgery, in robot-assisted operations surgeons need to see or induce visual indicators to guide their operation, because there is no tactile (haptic) feedback from the robotic device. All members of the team in the operation room see the operation online, and can anticipate forthcoming tasks. The robotic device is expensive and surgeons need to operate often to maintain their good performance using the robot, which increases specialisation and inter-organisational centralisation.

The operative team often consists of two surgeons, two assisting nurses, an anaesthesiologist, and an anaesthesia nurse. Our research focuses mainly on the work and learning of the surgeons, in which the principal surgeon is responsible for controlling the robotic instruments and the camera at the console, distanced from the body of the patient, while the assisting surgeon is next to the patient and handles and transports instruments. The whole team mediates the control of the robot and the surgical operation: the operating room nurse positions the devices, monitors and records patient and operation data into the computer and maintains telephone contact with other hospital functions and the outside world. The anaesthesiologist and the anaesthesia nurse mainly monitor and control the state of the patient, but they may also help in other tasks.

Our empirical study, the methods and data sources of which are more comprehensively reported elsewhere (Seppänen, Kloetzer et al., 2016; Wahlström et al., submitted), is in urology; the surgical management of carcinoma of the prostate, an area in which an almost revolutionary introduction of robotic-assisted

surgery has taken place. The main objective of this robotic surgery operation is to remove the cancerous prostate gland from the patient's body (Figure 1). The surgeon must be careful not to damage important adjacent structures. If the surgeon dissects the prostate too near the prostate surface, there is a risk that some cancerous tissue may remain. The correct dissection plane is estimated by preoperative studies, such as blood tests, radiological images, and prostate biopsies. The challenges of learning and operating centre around the boundary between the cancerous tissue of the prostate to be removed, and the surrounding tissues, organs and nerves that need to be saved as well as possible. Based on this, we sketch '*mastering the boundary*' as an initial germ cell of this activity.

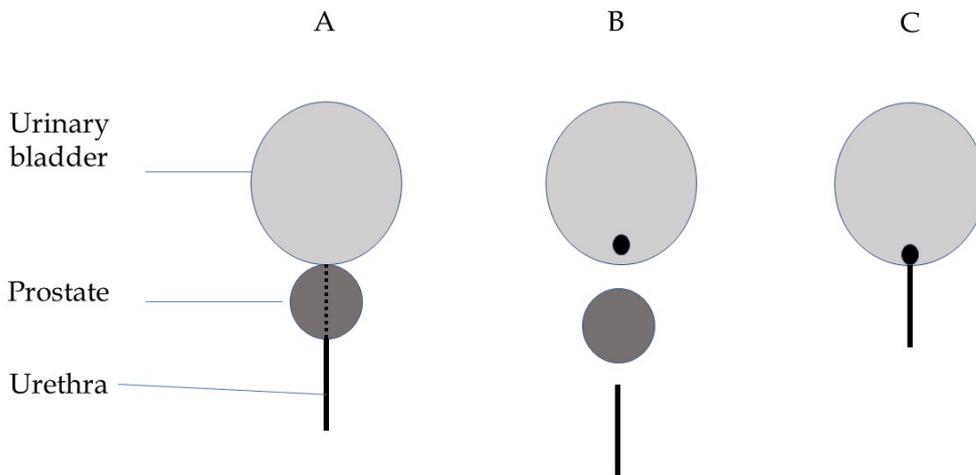


Figure 1. A rough sketch of the radical prostatectomy. A. Original location of the urinary bladder, the prostate and the urethra that goes from the bladder through the prostate. B. In the operation, the prostate is separated and removed. C. The urethra is reconnected to the urinary bladder. (Simplified from Taari, Aaltomaa, Nurmi, Parpala & Tammela, 2013; see also Seppänen, Kloetzer et al., 2016).

After the prostate is removed in the operation (Figure 1), it is taken to pathological examinations to discover exactly the place and quality of its cancerous tissue. Sometimes, *positive margins* are discovered. This means that cancer cells are found on the surface of the removed prostate. This is not desirable because some cancerous tissue may have remained in the body, although only about 30% of positive margins imply growth of cancer in the body after the operation. Positive margins are, we argue, a manifestation of the central contradiction of this surgical activity, and at the heart of the preliminary model of mastering the

boundary. Next we look at the learning designs and how their ideas were formed.

Three designs for learning

Our study involved video-stimulated self-confrontation events that have been transcribed and reported more specifically elsewhere (Seppänen, Kloetzer et al., 2016; Seppänen, Kloetzer & Riikonen, 2017; Seppänen & Riikonen, 2016). When analysing the data of video-stimulated self-confrontation events, three themes, or developmental objects emerged that seemed to be significant from the perspective of surgeons' work and learning. These themes seem to arouse motivation for learning and therefore constitute an important element in the learning process. The first theme is identification of tissues or organs, especially their boundaries and shapes. The second important theme is actions and practices on the boundaries, which means that variance in action, as rendered visible by video clips and surgeons' knowledge and experience, is a source of learning. Thirdly, motivation for learning may come from the conditions or phenomena that prevent surgeons from knowing or acting. We call these knowledge gaps, which can be handled with systemic analysis of boundary zones. One example of why the third theme is important is the uncertainty related to positive margins, explained in the section *Oncological robotic surgery* above. We combine these three developmental themes with our preliminary germ cell, which is the concept of mastering the boundary. One learning design is sketched for each theme. The designs below cover both small and local, and large ambitious learning efforts.

Identification of boundaries

We learned from the surgeons that identification is a challenge they very concretely face when learning robotic surgical operations, and this motivates their learning. Even though the image produced by the robotic camera considerably improves surgeons' vision compared to open surgery, the visual identification of tissues and organs must be learnt without palpation (touching and feeling), and as mediated by the digital video view. The identification challenge is partly due to anatomical variance in patients' anatomy which cannot be totally anticipated by pre-operative examinations.

Most importantly, the surgeons learn the identification when they assist in robotic operations (see the section *Oncological robotic surgery*). Before being able to operate as responsible main surgeons at the console of the robot, they may see tens or hundreds of operations and thus develop their vision for identification. They may create for themselves conceptions of 'right' places and ways of operating in different phases – partly standardised mental models that help and speed up the operation. Nelissen and Tomic (1996) call these *iconic representa-*

tions, meaning that the correct way to act is judged on the basis of a general, average image. An iconic representation most likely works well in standard operations, but it may lead to trouble when the patient has a special anatomy, or when the location of the cancer differs from the information obtained through pre-operative examinations. Iconic representation does not help surgeons perceive the systemic relations between a patient's particular anatomy, the occurrence of the cancer, the various health outcomes of the operation, and surgeons' action options. Nor does iconic representation account for the grounds of the formation of these phenomena. Special anatomies or disturbances in the operation process are the external stimuli that activate motivating cognitive conflicts (Engeström, 1994; Sannino 2015, p. 10) for surgeons, producing uncertainty or hesitation. The conflict may also be socio-cognitive, as surgeons are accountable for patients, their peers and the health care community as regards their operation outcomes. Theoretical thinking may be enhanced if the experienced surgeon at the console explains these relations, in occurrences of dysfunctions or anomalies, to the assisting surgeon during operations.

Video-mediated evaluation and reflection of operation actions efficiently supports identification, especially when it focuses on operation phases relevant for the learner (or, as made relevant by the information on patient records). It is not only about identification, but also about how local and situational identification is connected to the general complex surgical activity, and the learning surgeons to their intentions, feelings and knowledge. In addition to visual perception, identification also includes gestures and motoric movements through which surgeons induce visual information for identification. In other words, tissues are identified partially via their resistance to manipulation. Identification also involves situational synthesis of visual markers – objects are not simply seen, but inferred on the basis of various forms and colours depending on their location inside the patient's body. Furthermore, the space within which identification takes place is actually created by the surgeon as they open up the path towards the organ to be removed – the way in which the surgeon operates in the early phases of the surgical operation influences how easy it is to identify objects in later phases of the surgery: so-called landscape-making (Wahlström et al., submitted) is required. All these features point to the complexity of the identification task.

Identification could be learnt in a light way, as separate encounters between colleagues for watching the video clips. In this case, surgeons would learn about particular cases, but the enrichment of the involved knowledge would remain perhaps less systematic and less collective as compared to constructing a conscious and collective orientation basis. It would be important that senior surgeons, with their skilled vision, could participate in the encounter and help learners with identification. A practical condition, though, is that someone, most probably the learner him/herself, looks for interesting or demanding op-

eration cases in patient records, and finds the operation phases from the digital videos corresponding to the cases. All this takes time in busy hospital work. Digitally marking the phases of general interest and relevance on the video already during the operation would speed up this work.

Actions and practices at the boundaries

Here, the object of examination turns from the patients' features to the surgeons' own actions, or those of their colleagues, the final aim of which is to release the cancerous organ or tissue from its environment. This method may follow the steps of the self-confrontation method, which is efficient in 'generalising downwards' by developing the local and concrete work practice itself (Clot, 2009, p. 289). First, in *simple self-confrontation*, a surgeon watches, explains, and reflects on the actions seen in the video, above all to him-/herself, but also to another support person. The support person's status as external or internal to the surgical domain considerably affects the quality of reflection. The presence of an external person prompts surgeons to articulate the issues that are self-evident or implicit, as explaining to a peer surgeon is professionally more evaluative.

Based on our analysis, the real operative situation as seen in the video, and the patient record information directing its interpretation, are relevant elements in generating reflection, but the support person can also enhance reflection through open questions that extend the learner's horizon of possibilities. *Would it be possible to act otherwise, what are the risks here, and what is particularly remarkable in this situation* are such questions (Seppänen et al., 2017). The support person can direct the learner towards reflecting on how learner's actions relate to patient health outcomes, such as improving the removal of the cancer or diminishing the ill effects of the operation. The learner can also be directed to evaluate his/her performance according to concepts or categorisations of their professional domain.

Second, in *crossed self-confrontation*, the same video-mediated work situations are jointly reflected on between peer surgeons and a researcher. The variance created by watching different ways of enacting the same practices or distinct actions in similar situations is a powerful source of learning (Pihlaja, 2005)¹. The variety of audiences forces surgeons to express the same actions or situations in different ways, which opens up possibilities for new interpretations (Seppänen, Kloetzer et al., 2016). Self-confrontations rightly remind us that no model is useful for practitioners unless they take and enrich the model as their own instrument of activity. The orientation basis and the construction of the 'abstract' model is embedded in a broad set of practitioners' tools and knowledge (Engeström, 1994, p. 34). The principles and steps of crossed self-confrontations have been described in more detail elsewhere (Clot, 2009; Kloetzer, 2012; Seppänen & Riikonen, 2016).

Joint reflection between peer surgeons seems to be useful, particularly if the peers have not been operating together as a pair of main/assisting surgeons. The third stage of the self-confrontation method, a collective encounter of peers for common reflection of the same video clips, could be applied in scientific conferences, or in virtual meetings between different hospitals offering robotic surgery.

Systemic analysis of boundary zones

Surgical knowledge, which is embedded in bodily movements, is partly tacit – but still based on medical science – and thus not easily transferable from one professional to another through standards. Our data and findings, together with the idea of modelling in the method of theoretical thinking, offer interesting insights not only to organising and representing existing knowledge in a new way, but also to systematic creation of new knowledge regarding this particular surgical domain, and for developing corresponding new techniques.

In our data, many of the surgeons' initiatives focused on the operation phases in which, based on patient records, positive margins were formed (see the section *Oncological robotic surgery*). Positive margins seem to arouse cognitive conflict in the form of questioning or hesitation and consequently a need for theoretical thinking. Surgeons were especially interested in watching and reflecting on the phases in which the positive margin side of the prostate was released. The information regarding positive margins, either in general or occurring in some specific location, could be collected from patient records. By examining video clips of corresponding operation phases of the same patients, it would be possible to chart different causes for positive margins, and gain new knowledge regarding the conditions and action options for managing this phenomenon. We assume that positive margins manifest the central contradiction of oncological robotic surgery and that they are at the heart of the 'mastering the boundaries' germ cell. In addition to new knowledge regarding the distribution of the cancer, the variation of the form of the prostate could be better understood, and perhaps virtually modelled. The videos made by the robot can thus be a vehicle for collective learning through research of this kind.

It is notable that surgery being a largely science-based activity implies a kind of uncertainty: like any science, medical science is not perfect, and surgical practice therefore progresses hand-in-hand with the scientific activities of surgeon researchers. Surgical work draws from inferring the features of human anatomy as well as from statistical studies in which patient recovery and health is contrasted against different surgical methods and practices – from reading medical descriptions of procedures (Su & Smith, 2012), it is apparent that there are scientific debates on where and how certain tissues should be dissected exactly. Systematic analyses of the actualised operations could provide a basis for hypothesis creation for medical inquiry: if the surgeons find out, for example,

that there is variance between their actual work practices and that there is the looming possibility that these could influence, for example, the positive marginal results, these thoughts could be tested by orchestrating experimental research (that is, comparing one work practice to another in a number of patients). According to data, videos were previously used for micro-anatomical location of erectile nerves, and for developing nerve-saving operation techniques. Digital marking of certain critical phases in the videos already during the operation is also necessary for this method.

We have now looked at the learning of theoretical-genetic thinking, presented the work context in which expertise is needed, and suggested three preliminary designs based on surgeons' learning needs in robotic surgery. The next section will apply the steps of learning theoretical thinking in the activity of robotic surgery.

Steps of learning theoretical thinking in robotic surgery

Following the process of developmental instruction (Engeström, 1994) and based on the learning designs above we suggest that methods for surgeons' learning, in order to both improve concrete operations and produce general knowledge, should include the following steps.

Arousal of motivation. Professionals' learning at work is motivated by the questions they face in their work. Motivation for surgeons is aroused by focusing the joint watching of video clips on features and surgeons' actions when operating those phases that cause cognitive conflicts. For instance, the identification of tissues in a crucial phase of operation, in our data, is a cognitive conflict for surgeons starting out in robotic operations: it cannot be solved with knowledge from books only, nor with experience in traditional open surgery. For surgeons already experienced in robotic operations, in turn, identification may come automatically. For them, mismatches between the expectations and outcomes of operations prompt motivating conflicts. Instances of positive margins are such mismatches. Learning a new operation technique that has proven, in research, to be beneficial for patients' recovery can be motivating for all.

Orientation. Conscious building of orientation is a crucial part of learning theoretical thinking, to which developmental instruction needs to pay special attention. In this, learners form a preliminary orientation basis that helps them structure the knowledge needed for solving a problem such as a cognitive conflict in the previous step. Discovering and shaping an orientation basis is an instructional task in itself. Therefore, a ready orientation basis provided by instructors does not suffice. An orientation basis, or several competing sketches for such, are arrived at by utilising learners' own experience and experiments (Engeström, 1994, p. 75). We sketched 'mastering the boundary' as a germ cell of oncological robotic surgery. For the purpose of orientation in instruction,

however, this is too abstract, unconnected from the practical surgical activity. Mastering the boundary can rather be used as a principle for directing the way in which learning surgeons watch the video-clips of an operation, or how they articulate the crucial elements and functionally relevant relations during a particular phase of an operation. For instance, several competing sketches of how to identify the correct place for cutting can be made jointly visible by writing them down on a wall. As our data shows, some surgeons rely on one or two signs for identification, while others infer the correct place for cutting by using several visual cues in the landscape. Based on these competing sketches, it is possible to outline a general initial orientation basis, to be elaborated further. An orientation basis should serve as an aid for thought or as a map to guide real task performances.

Internalisation. By interpreting a certain operation phase as seen in video-clips of many different operations in the light of the orientation basis formulated in the previous Step 2, learners both enrich the orientation basis and start using it. Through this process, some parts of the orientation basis gradually transform into the learners' internal mental model. Moreover, new elements and objectives need to be incorporated into it. For instance, simultaneously with identification and cutting, surgeons need to investigate the size and shape of the prostate. How this is done needs to be included in the orientation basis. One also has to identify some delicate tissues and avoid touching them. Moreover, a new technique, proved beneficial for patients' recovery, will radically change the conditions of identification. The orientation basis thus grows in complexity. There is a risk of drowning in a sea of endless details, and therefore the instructor continuously supports surgeons' articulation of general and functionally important features and elements. Moreover, by answering why-questions, learners connect the operation situation visible in the videos to the pre- and post-operation information of the patient. Use of patient records thus constitutes part of instruction, providing temporal sense for operative actions and making visible origins of phenomena or revealing information uncertainties. An evolving orientation basis can be represented in many ways and be used to create concrete practical guidelines. Elaboration of an orientation basis requires a great deal of work. As visual perception is central to this activity, the orientation basis could be built on a digital visual learning tool that surgeons themselves can continuously modify and enrich.

Externalisation. While previous steps take place in joint video-stimulated learning events, externalisation happens in the productive surgical activity. The main point of the orientation basis is to be able to look at the concrete specific surgical actions and environments, not as something sensually concrete, but as contextual, systemic knowledge of the object in question (Engeström, 1994, p. 93). In externalisation, surgeons consciously use the orientation basis in their operations for better structuring and judging the involved elements and actions.

The assumption is that the orientation basis would help see or induce some similarities between the situations, and that this, in turn, would yield improved decisions and actions in particular operations. In other words, an orientation basis is a vehicle that helps connect situations of particular patient operations to general systemic knowledge of oncological robotic surgery.

Critique and control. It is important to organise opportunities for surgeons to critically evaluate and control both their own learning and the evolving orientation basis. This can be done again by watching video-clips of critical operation situations and interpreting the actions in the light of the orientation basis. This is a two-way process: surgeons evaluate their operation situations with the orientation basis, and they critically evaluate its validity and usefulness on the basis of experience in its use. The orientation basis needs to be modified accordingly. If properly elaborated, it may offer criteria for quality control of robotic surgery in the hospital.

Discussion and conclusion

In this article of sketching developmental instruction for learning in robotic surgery, we started with the notion of theoretical-genetic thinking and its principle of ascending from the abstract to the concrete as possibilities to enhance learning to cope with complexity, uncertainty and technology-mediation in work. This, together with our attention to the surgeons' learning challenges in robotic operations, has informed us of how theoretical thinking could be developmentally instructed in robotic surgery.

The insights of this article will be examined and elaborated together with hospital surgeons and trainers. If successful, the learning method can in turn support professional education and training professionals in their work. The same principles, in our opinion, apply to vocational training as well.

Our argument, derived from the theory of theoretical generalisation, is that the learning method sketched here would deepen surgeons' learning, improve their learning abilities, help create both general and situational new knowledge and thus improve the quality of robotic operations and their outcomes. Our previous analyses have shown how surgeons' field of actions, directed by medical terms, is in reality ambiguous and uncertain. This requires constant interpretation of the micro-anatomic cues (Wahlström et al., submitted) and theoretical thinking. Professionals do also construct their orientation bases without external efforts of training or instruction. The method of theoretical thinking suggests that in the future, we analyse in detail how surgeons create and use orientation bases and theoretical generalizations by, for example, moving between features of particular cases and general knowledge. In practice, developmental instruction may require close collaboration between practitioners, HR developers and researchers (Virkkunen & Schaupp, 2011).

Alvunger and Adolfsson (2016), in introducing their critical dialogical model for vocational teacher education, emphasise the importance of enacting the interface between theory and practice in enhancing students' learning. The method presented in this article deals with the same interface, but in a different way: the aim is to build 'theory', through visualising and elaborating orientation bases, from complexities of practical work activities. The content of learning originates from the contents of activities people face in their work.

Our studies of robotic surgery suggest that the combination of patient record information showing dysfunctions or anomalies in the course of the operations, and collectively watching the corresponding real phases of operation situations as seen in the video-clips is a promising path for learning (Seppänen et al., 2017). Collective elaboration of an orientation basis as a dynamic model is a key feature in the proposed method. The use of videos, and digital means for learning by modelling, may offer new possibilities for developmental instruction that need to be investigated further.

Contentful theoretical thinking has two different directions: producing general, abstract understanding about dynamic interrelations within a phenomenon, and flexibly tailoring good solutions for each particular work situation. The latter is particularly important in the clinical work of hospitals and surgery. The methodology of self-confrontations used in our study can contribute to theoretical thinking by highlighting 'generalisation downwards' and seeing one's own and collective work activities in new ways. The challenge now, from the perspective of theoretical thinking, is to make orientation bases collectively visible, evaluate them in terms of their ability to help with concrete problematic situations in robotic operations, and to constantly develop them. We assume that a common orientation basis which is able to extract relevant features and relations within complex activities co-evolves with professionals' learning of theoretical thinking. Here we have initially outlined some ideas on how this might proceed. Possibilities for such a process need to be tried out in practice.

Endnote

¹ Here, Pihlaja (2005) refers to Marton, F. (2000). *Variatio est mater studiorum*. *Magyar Pedagógica*, 100(2), 127-140.

Acknowledgements

We cordially thank the surgeons, other operation room personnel, hospital developers and managers for their participation and support. The project 'Interpretive work: Developing new forms of work-based learning for the age of digitalisation' is part of The Future of Learning, Knowledge and Skills research programme of the Academy of Finland, and it received funding from the

Finnish Environment Fund. This article was made possible with funding from the Academy of Finland (Strategic Research Council, decision 303669 13.06.2016).

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References

- Alvunger, D., & Adolfsson, C.-H. (2016). Introducing a critical dialogical model for vocational teacher education. *Nordic Journal of Vocational Education and Training*, 6(1), 53–75.
- Boud, D., Cressey, P., & Docherty, P. (2006). *Productive reflection: Learning for changing organizations*. London: Routledge.
- Clot, Y. (2009). Clinic of activity: The dialogue as an instrument. In A. Sannino, H. Daniels, & K. Gutiérrez (Eds.), *Learning and expanding with activity theory* (pp. 286–302). Cambridge: Cambridge University Press.
- Clot, Y. (2011). *Travail et pouvoir d'agir* [Work and power to act]. Paris: Presses Universitaires de France.
- Davydov, V.V. (1990) *Types of generalization in instruction: Logical and psychological problems in the structuring of school curricula*. Reston, Virginia: National Council of Teachers of Mathematics.
- Davydov, V.V. (2008) *Problems of developmental instruction: A theoretical and experimental psychological study*. International Perspectives in Non-classical Psychology. New York: Nova Science Publishers, Inc.
- Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research*. Helsinki: Orienta-Konsultit.
- Engeström, Y. (1994). *Training for change: New approaches to instruction and learning in working life*. Geneva: International Labour Office.
- Engeström, Y., Nummijoki, J., & Sannino, A. (2012). Embodied germ cell at work: Building an expansive concept of physical mobility in home care. *Mind, Culture, and Activity*, 19(3), 287–309.
- Ilyenkov, E.V. (1982). Dialectics of the abstract and the concrete in Marx's capital. Moscow: Progress. Also available at (retrieved 20. February, 2017): <https://www.marxists.org/archive/ilyenkov/works/abstract/>
- Ilyenkov, E.V. (2007). Our schools should teach how to think. *Journal of Russian and East European Psychology*, 45(4), 9–49.
- Kloetzer, L. (2012). Development of professional concepts through work analysis: Tech diving under the loop of activity clinic. *Mind, Culture, and Activity*, 20(4), 318–337.
- Kloetzer, L., Clot, Y., & Quillerou-Grivot, E. (2015). Stimulating dialogue at work: The activity clinic approach to learning and development. In L. Filletaz, & S. Billett (Eds.), *Francophone perspectives of learning through work: Conceptions, traditions and practices* (pp. 49–70). Dordrecht: Springer.
- Langemeyer, I. (2014). Learning in a simulation-OT in heart surgery and the challenges of the scientification of work. *Journal of Education and Work*, 27(3), 284–305.
- Nelissen, J.M.C., & Tomic, W. (1996). Reflection in Russian educational psychology. *Educational Foundations*, Winter 1996, 35–56.

- Norros, L. (2017). Understanding acting in complex environments: Building a synergy of cultural-historical theory of activity, Peirce, and ecofunctionalism. *Mind, Culture, and Activity*. Published online: <http://www.tandfonline.com/doi/full/10.1080/10749039.2017.1350714>
- Norros, L., Savioja, P., & Koskinen, H. (2015). *Core-task design: A practice-theory approach to human factors*. Synthesis Lectures on Human-Centered Informatics #27. Penn State University: Morgan & Claypool Publishers.
- Pihlaja, J. (2005). *Learning in and for production: An activity-theoretical study of the historical development of distributed systems of generalizing*. Helsinki: Helsinki University Press.
- Sannino, A. (2011). Activity theory as an activist and interventionist theory. *Theory & Psychology*, 21(5), 571–597.
- Sannino, A. (2015). The principle of double stimulation: A path to volitional action. *Learning, Culture and Social Interaction*, 6(2015), 1–15.
- Seppänen, L., & Riikonen, J. (2016). Learning interpretativeness for sustainability: Exploring the self-confrontation method in robotic surgery. In A. Harju, & A. Heikkinen (Eds.), *Adult education and the planetary condition* (pp. 124–133). Helsinki: Finnish Adult Education Association. Published online: http://issuu.com/svv-ohjelma/docs/adult_educ_planetary_cond_2016?e=15627691/36835887
- Seppänen, L., Kloetzer, L., Riikonen, J., & Wahlström, M. (2016). A developmental perspective to studying objects in robotic surgery. In L. Introna, D. Kavanach, S. Kelly, W. Orlikowski, & S. Scott (Eds.), *Beyond interpretivism? New encounters with technology and organization*. Springer International Publishing: IFIP Advances in Information and Communication Technology Vol. 489, pp. 229–245.
- Seppänen, L., Kloetzer, L., & Riikonen, J. (2017). Encourager la réflexion en chirurgie robotique: L'auto-confrontation croisée comme instrument de développement du travail interprétatif dans un environnement technologique complexe [Encouraging reflection in robotic surgery: Crossed self-confrontations as an instrument for developing interpretive practice in a complex technological environment]. *Psychologie du Travail et des Organisations*, 23(2), 117–136.
- Su, L.-M., & Smith, J.A. (2012). Laparoscopic and robotic-assisted laparoscopic radical prostatectomy and pelvic lymphadenectomy. In L.R. Kavoussi, A.C. Novick, A.W. Partin, & C.A. Peters (Eds.), *Campbell-Walsh urology*, 10th edition (Chapter 103, pp. 2833–2843). Philadelphia: Elsevier Inc.
- Taari, K., Aaltomaa, S., Nurmi, M., Parpala, T., & Tammela, T. (Eds.). (2013). *Urologia*. Helsinki: Duodecim Medical Publications Ltd.
- Virkkunen, J., & Ahonen, H. (2011). Supporting expansive learning through theoretical-genetic reflection in the Change Laboratory. *Journal of Organizational Change Management*, 24(2), 229–243.

- Virkkunen, J., & Schaupp, M. (2011). From change to development: Expanding the concept of intervention. *Theory & Psychology, 21*(5), 629-655.
- Wahlström, M., Norros, L., Seppänen, L., Schaupp, M., & Toiviainen, H. (2014). Interpretative work: Developing new forms of work-based learning for the age of digitalisation (WOBLE). Retrieved 15. February, 2017, from https://dl.dropboxusercontent.com/u/11126152/Woble_research_plan.pdf
- Wahlström, M., Seppänen, L., Norros, L., Aaltonen, I., & Riikonen, J. (submitted). Resilience in through interpretive practice: A study of robotic surgery.