Distributed systems of generalizing as the basis of workplace learning

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Abstract *This article proposes a new way of conceptualizing workplace learning as distributed systems of appropriation, development and the use of practice-relevant generalizations fixed within mediational artifacts. This article maintains that these systems change historically as technology and increasingly sophisticated forms of production develop. Within these parameters, Taylorism is analyzed as the principal form of the learning systems of mass production, and the total quality management as the learning system of flexible manufacturing, or continuous improvement of processes, as it is also called. The article also maintains that the current IC technology-based transformation of businesses increasingly calls for meta-level learning, which makes it possible for the stakeholders within a given system of production to flexibly transform their system of producing generalizations, as the business concept's life cycle proceeds from one phase to another.*

Introduction: the need for a historical approach

The ongoing globalization of markets, innovation-based business competition and the informatization of work using the new IC technologies are currently changing the overall structures of production and management. In addition, forms of generating, accumulating, and passing on knowledge are also in the process of change. According to Freeman and Louça (2000), these changes compose just one part of an ongoing shift in the techno-economic paradigm within the industrialized countries. The former mass-production paradigm that was based on cheap energy is now being replaced by new emerging forms of production and exchange that make effective use of the information that has been made economical by the new IC technologies. To understand how this change affects workplace learning, we must study both work and learning as two historically changing phenomena.

In this paper, we will propose a way of analysing workplace learning as a distributed system of production and the use of work-related generalizations that are fixed in mediational artifacts. This way of conceptualizating workplace learning, we believe, helps to clarify the dialectical relationship between individual and organizational learning, and to analyze the changes that are taking place in workplace learning. We will first present the idea of learning as a process of artifact-mediated generalizing. Then, we will discuss three levels of mediational artifacts, as well as the different sorts of processes that produce practice-relevant generalizations. In these analyses, we will rely on the cultural historical theory of activity. We will analyze the systems of workplace learning

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of three historical forms of production, handicraft, mass production and flexible mass production, applying the proposed concepts. Finally, on the basis of these analyses and through an empirical case example, we will discuss the nature of the current challenges facing workplace learning.

Learning as the appropriaton and creation of generalizations

According to Leontyev (1933), a physical tool reifies a specific cause-effect relationship that is utilized to carry out a recurrent task in any given human practice. As a tool is developed, a set of objects becomes delineated as workable with that specific tool. In effect, both the tool and the way it is used make use of certain common properties of these objects, as well as a general causal relationship. In this sense, we can say that there is in each tool embedded an abstraction and generalization. Also concepts that form the meanings of words are generalizations that abstract features in objects and situations that are important for a specific human practice, as Vygotsky (1987) has shown. The cooperative use of physical tools is not typically possible without a corresponding set of signs and words that are used as tools for coordination and communication. On the one hand, human cooperation is not possible without engaging in generalizations that are fixed in signs, symbols and tools. On the other hand, such generalizations can only develop within peoples' collaborative activities and communications (Leontyev, 1933).

Culturally developed artifacts also serve the function of linking individual and cultural learning. Individuals internalize the signs and symbols that were originally used in social interaction, and use them also as their individual psychological tools for self-regulation and thinking (Vygotsky, 1987, p. 148). They do not, however, simply appropriate culturally developed generalizations that have been preserved in language and tools, but construct additional generalizations from their own experience. Individuals synthesize constantly their immediate experience and the cultural generalizations, in order to provide the mental foundations of their real-time actions (Cole and Engeström, 1993, p. 6). Of special interest in this process is the creative interplay between everyday concepts that develop "upwards" from an individuals' personal experiences and scientific generalizations that "grow downward" to individual and local applications and concretizations (Vygotsky, 1987, p. 108).

Concepts or tools are not in-and of-themselves generalizations. Rather, they serve to mediate generalized operations in the same way that a hammer mediates the operation of hammering. To appropriate a tool or concept means that one learns to perform the specific generalized operations of perceiving, thinking, communicating or practical action that the artifact has been created for (Leontyev, 1933). Wartofsky (1979, p. 201) differentiates between primary and secondary artifacts. Primary artifacts are those that are directly used in production, such as tools, modes of social organization, and bodily skills that enable the use of tools. The representation of actions by symbolic means

generates the distinctive class of secondary artifacts, including models of forms of action, designs and prescriptions that are "... created for the purpose of preserving and transmitting skills, in the production and use of primary artifacts". Secondary artifacts make it possible for practitioners to take an overall view of their activity, and then to reflect on it, as well as to collect and save their experiences as potential material for further development of the work.

According to Wartofsky (1979), there are also tertiary artifacts that do not have a direct representational function but instead serve the free construction, in the imagination, of tools, rules and operations that are distinctively different from those adopted for the praxis. Such "possible worlds" may in fact reflect the limits of the actual praxis, and can help the practitioners to create alternatives for conceivable change in the model of praxis itself. We can go so far as to say that secondary artifacts serve as tools for reflecting upon, evaluating and developing primary artifacts, while tertiary artifacts serve as tools for reflecting upon, evaluating and transforming both secondary and primary artifacts.

Generalization is only possible on the basis of variation that makes it possible to identify similarities and differences (Marton, 2000). An actor's interaction with external objects which is mediated through tools and concepts makes up a natural experimental setting for controlled comparisons, as the actor can test the impact that different tools have on the same object as well as the impact a specific tool has on different objects. The generalizations fixed in artifacts, on the one hand, and processes of generalization, on the other, are in a dynamic, dialectical relationship with one another. They form a unity of opposites, and functionally permeate one another. In action, tools and concepts become parts of a process that winds up producing changes in them. Actions link generalizations to practice and the subject with reality. According to Leontyev (1933) it is this dialectical relationship between generalizations and the process of generalizing that is the pivotal key for understanding learning, and not the difference between internalized, mental representations and processes, on the one hand, and external material representations and external action, on the other.

The nature of the generalization that is embedded in a sign or tool is not apparent within the artifact itself. It can only be revealed through tracing the process of generalizing that led to the generalization. These processes can be analyzed using Leontyev's theory of the hierarchic structure of human activity. According to Leontyev (Leont'ev, 1978) there are three interconnected systemic levels in human activities: the system of societal activity with a specific object and outcome; individuals' actions that realize specific objectives within the system of joint activity; and operations through which one's actions are carried out. In Leontyev's terms, the process of generalizing in a work activity can be based on operations that are carried out in the midst of other operations that

are necessary to accomplish a productive action as, for example, when an actor in passing changes a tool or the way of using a tool while accomplishing a task, and such a change prevails. The process of generalizing can also be based on conscious actions of generalization that are taken in the midst of actions of production within an activity. One example of this might be seen when a manager uses a decision as the precedent for cases still to come. Producing concepts and tools for mastering an activity can also be a specific form of collaborative activity that is realized through chains of actions needed for reaching new generalizations. This is certainly the case in scientific research and in many design and planning activities.

From the tradition-based system of generalizing to conscious actions of generalization

In the late 1800s, the owners of factories made a contract for the work to be done with a foreman, who was to lead a group of workers. In these groups, the skill and competence of carrying out the work was preserved in traditional methods and "rules of thumb", as is typical of craftwork. In this form of activity, generalizations concerning effective work methods were primarily produced through incremental adjustments and improvements regarding the work implements and the methods for using them. These changes were to a great extent made through operations within actions of production. A good example might be a worker developing a motor or mental representation of an effective way to realize a recurrent action, or changing a tool to make it more appropriate for the task at hand. The results of this accidental process of generalizing were predominantly fixed by changing the primary artifacts, and the workers' perceptual-functional representations of various tasks and action situations. In the lack of well-developed secondary artifacts, the generalizations could only be transmitted to new generations of workers through a process of "legitimate peripheral participation" and apprentice in the productive activity as well as through rough rules of thumb.

In the late 1800s, the invention of the electric motor and a set of further complementary innovations led to the new principle of arranging layouts of industrial plants as centered upon production lines, which were laid out according to the successive phases of manufacturing a specific product (Hirschhorn, 1986). The idea of the production line became a central generalization regarding effective mass production. The overall output of a production line comprising mechanical machines depended, however, to a great extent on the speed of the manual operations that could not be mechanized. In this situation, Taylor (1911) developed a new way to improve the method of performing specific manual tasks in a system of production. He collected a few workers who were particularly skilful in the specific work in question. Then, Taylor separately studied the exact series of work motions each of these men used when performing his task, and selected the optimum sequence of motions,

and the quickest possible way of carrying out each motion. The result of this process of forming a generalization from varying individual performances was in fact a secondary artifact, which became known as the work standard. It described the fair amount of work that could be expected from a workman who was performing a specific task, and "the one best method" for performing the task. Each worker was subsequently taught and obliged to carry out the task according to the standard created for it. The standards of the work tasks set the frame for the individual workers' workplace learning.

This systematic analysis of the various ways to carry out a task only become possible on the basis of the previous generalization that work is in fact comprised of identifiable "tasks". This concept delineated the object of attention and the sphere of variation used as the basis for learning. This new form of generalizing that comprised the conscious actions of searching out the optimal form and sequence of work motions to be used to perform a task, was, according to Taylor, only possible when a group of people specializes in carrying out these actions. Taylor proposed that every industrial plant should maintain a planning office of specialists who devoted themselves to producing and teaching standards for the work tasks in its production process. Thus, a new subject-object relationship needed to be institutionalized, in which the work-study specialists became the subjects, and the optimization of the way workers performed their work tasks became their object. During the long period of economic growth after the Second World War, this system of generalization which Taylor called "scientific management" spread out in various forms, as part of the permeation of the principles of mass production into almost all areas of human activity.

After the so-called "oil crisis" of the 1970s, a new way of flexibly mass producing a variety of quality products spread all over the world, as well as to diverse areas of activity (Womack *et al.*, 1990). This model was initiated after the Second World War in the Toyota car factory on the basis of partial automation (Ohno, 1978). It was later theoretically elaborated upon by engineer Kaoru Ishikawa (1990). In this system, production line has been replaced with a flexible, order-based production flow within a network of subcontractors. In this type of production, work is performed in teams. The workers are obliged to halt production if they recognize an error or threat of disturbance. In order to determine the causes of disturbances, waste, and quality problems in the production, the workers in flexible mass production use a set of analytic tools collaboratively in special social formation of quality-control circles discussing also with the firm's production planners. After establishing the cause of an identified problem, they use a process of experimentation to solve it and to improve the work standard in question, which they subsequently keenly follow as they go on with their production activity (Victor *et al.*, 2000).

Because, in the state of flexible mass production, a set of different products are produced on the same production line, there is far more variation in the production than might be found in a more traditional form of mass-production. The initial generalization that constitutes the object of attention in the continuous improvement of working processes in the flexible mass production is not a "task", as it was in Taylor's scientific management, but a "problem". The source of variation that the generalizations that provide the solutions to the problems are based on is not a set of individual ways of performing the same task, but is rather the varying functionality of optional ways of arranging a specific detail within the production flow. In flexible mass production as well, the practice of production is rendered into the object of actions of generalization with the aid of work standards as the secondary artifacts. In this case, however, the same workers flexibly switch the object of their attention from centering on production according to the standard into developing the standard-and back, from taking productive actions to taking actions of generalization and back to taking, this time somewhat altered, actions of production (Victor *et al.*, 2000). The standards that are used as secondary artifacts, although they are to a great extent externally similar those involved in traditional mass production, are produced through a qualitatively different process of generalization, and are also applied to production in a qualitatively different way, and thus mediate a different generalization.

Generalization concerning a new principle of production

The principles of mass production and the continuous improvement of processed in flexible mass production were the tangible results of a determined and sustained activity of producing a new form of production (Taylor, 1911; Ohno, 1978). Such a collaborative activity indeed calls for specific expansive actions of generalization such as questioning aspects of the prevailing production model and practice, analyzing its inner relationships as well as its historical development, modelling a new principle for the production, examining the new model through conducting thought experiments, and finally transforming the practice through the experimental implementation of new tools (Engeström, 1999). In these actions, the object of attention, learning and development is not a specific task or problem-nor is it the optimal way to master the flow of production. Instead, it is the entire system and principle of production. The motive for creating a new form of production was obviously an emerging contradiction that was inherent in the existing one. The new principle of production was created by analyzing the contradictions inherent in the prevailing system, and combining elements from different existing cultural resources in order to create a new principle. The resulting new form of production became later a model that was used to solve similar developmental contradictions in other local production activities. The historically unique process of expansive generalization that led to the qualitatively new principle

and form of production was, in the both cases described above, Scientific management and total quality management, accompanied by a new distributed system of production-related generalization. In these systems, a new general production concept has set the stage for both perceiving and utilizing the available empirical variation in the production process for creating generalizations that incrementally improve the production.

It is not yet clear what forms of work will turn out to be most effective regarding the utilization of new resources of cheap information, as well as meeting the new challenges of continuous innovation and a global market. Some tentative observations regarding this development are, however, at least possible. Instead of a standardized product or service, today's firms are increasingly creating customized offerings that contain both products and services. Firms specialize in areas in which they can afford continuous research and development. The end results are increasingly produced in concurrent cooperation of many specialized firms in a star-like constellation, as opposed to the traditional value chain (Normann and Ramirez, 1994).

The most profound change, however, seems to be the accelerated pace of deep qualitative transformations regarding the principle of production itself. The two production systems discussed above were based upon the idea of linear development of production after the creation of the new production concept. Due to an increased investment in research and development, cycles of renewal regarding business-, product- and production-concepts have been summarily shortened. In order to master such cycles of transformation practitioners need new forms of production-related generalization, which would make it possible for them to take a reflective stance not only on individual tasks or problems, but to the historical transformation of both the object and principle of their production activity. This type of reflection on the historical transformation of an activity calls for expansive learning actions, as well as a new basic generalization that redefines the object of attention as a historically changing system of activity. It also calls for tertiary artifacts to serve as tools for the critical analysis of the present principle of the production activity, and for designing a new principle and new secondary artifacts needed in the new form of production activity. Besides this new level of mastery regarding the transformation of an activity, qualitatively new types of actions of generalizing are also often needed such as generalization through negotiation and collaborative prototyping.

An example of the change of the system of distributed generalization and learning at work as the business concept evolves

The telecommunications industry provides many interesting examples of changes regarding learning in and for work, because new information technologies in the telecom field radically change the logic of businesses, as well as the methods of using the old infrastructure of telephone connections. In

the following example from the "TC" telecommunication (a pseudonym) we can see some of the aforementioned current changes in the processes of production-related generalization and learning. The data concerning this example has been collected in a developmental intervention, in which the team in question analyzed the development of its work and designed a new form of their work along with an external researcher (Virkkunen and Ahonen, in press)[1].

In early 1990s, TC decided to develop a new product that consisted of computer connections for the use of PCs (ISDN). After the technical and commercial preparations had been made for the new product, the firm invited its telephone technicians to apply for a position on a new team of home-ISDN connection technicians, which was soon to be established. Before the new product was launched, the technicians selected for the team underwent a two-year regime of intensive training in ISDN and PC technologies. As the sales of the new product started, members of the new team began their installation work and continued to learn by performing installations. In difficult cases, they took extra time in order to solve problems and learn how to master different kinds of installations. The team members frequently met to discuss problems that occurred during the installations, and to further develop the evolving installation practice. In these meetings, they produced new generalizations concerning the installation methods. After an initial period marked by a slow increase in the amount of connections sold, the demand and sales of these connections exploded. A number of other teams of technicians were trained to perform ISDN installations, and the original team was given the responsibility of guiding the work of these teams, for handling especially difficult installations, for controlling the overall quality of the installations, and for further developing the overall installation practice. The original team was also expected to create profit by performing installations.

At that point the team took part in a developmental intervention called the competence laboratory, which was composed of six two-hour sessions weekly, a period of experimentation with new solutions, a follow-up and evaluation session, and various forms of data collection and planning before and between sessions. In this process, both the researcher and the technicians collected observations concerning resent problems and changes that had taken place during the short history of the team's installation work. When analyzing its situation, the team noticed that because of the increased workload, they no longer had time to solve problems together. Each technician tried to learn individually while doing his or her work. They strongly felt that they were caught in a double-bind situation regarding their new role; it was not possible for them to meet all the competing demands made on them.

During the first sessions of the intervention, both the team and the researcher collaboratively used the data collected by the researcher and the team members for the purpose of questioning aspects of the team's present

practice. In analyzing the systemic causes of the highlighted problems in their current practice, they used graphic models of the basic structure of an activity system and the cycle of expansive development of an activity (Engeström, 1978). Using these general models as intellectual tools, they constructed a tertiary artifact, a model of the qualitative change and phase of development of the system of their joint activity as well as the internal contradictions within it. This tertiary artifact helped the technicians to understand the roots of the problems they experienced during their daily work. This analysis also formed the basis for a number of important reforms in the team's activity, as well as the team's methods of developing generalizations concerning various aspects of their installation activity.

As one of the reforms, the team created a secondary artifact, a form for collecting data concerning problems in installations. This new tool enabled them to solve recurring installation problems on the basis of aggregate problem descriptions. The team began to meet regularly to discuss the installation problems on the basis of the collected data. Members of the team prepared the discussions in these meetings according to a new division of labor and areas of specialization between the team members. The team also initiated a new process of generalizing; a series of negotiations with its cooperation partners for the purpose of eliminating problems and finding a functional form for the cooperation with each cooperation partner. Such a negotiation took place for instance with the subcontractor who provided the ISDN cards for installation in customers' PCs, and it was this negotiation that led to an important reduction in the types of cards to be used, which made the installations easier and quicker.

In the generalizing system of flexible manufacturing, teams use secondary artifacts to solve problems and to improve the production process. Observations about disturbances and waste are used both as the starting point and as material for the process of problems solving. The participants in the competence-laboratory intervention used two tertiary artifacts, the models of an activity system and the model of the cycle of expansive development of an activity system, to envision a new principle for their activity, as well as for designing new secondary artifacts. The object of this process was not primarily to solve identified problems that would make the existing form of activity more fluent, but to create a new form and principle for the activity that would solve the deadlock created by the old principle. This new principle was based on a new, broader generalization about the object and motive of the team's activity as standardization of the installation practices. The collaborative intervention described above not only led to new processes of generalizing (one of these processes, the use of the problem form, highly resembles the principle of quality control circles), it also led to an important meta-level generalization. The team reconceptualized its activity as cycles of technology implementation and begun the task of transforming its historical experiences from the

development of the ISDN installation practices into future plans concerning ways to learn and master the development of installation practices for the next-generation technology, the ADSL.

We have found that two fundamental aspects are particularly important in the preceding example. First, the forms and distributed systems of generalizing within the home-ISDN installation team profoundly changed during the developmental cycle of the ISDN business. The process began with rather traditional training, in which the team members appropriated the theoretical generalizations, methods and tools of ISDN installation. This phase of technological appropriation was followed by a process of learning by performing ISDN installations, in which most of the generalizing took place as the technicians solved problems they encountered in their work. As the object of the team's activity expanded, this form of generalizing and learning led to a crisis. In the competence-laboratory process, using the theoretical generalization of an activity system and analyzing the historical changes in their activity with the help of the two tertiary artifacts, the team produced a new system of distributed generalizing. This new system was based on new kinds of actions of generalizing that took, with the help of the new tool, advantage of the increased variety of experiences the newly established local teams of technicians provided. The use of the models of an activity system and the cycle of expansive development as tertiary artifacts enabled the practitioners to adapt a reflective stance towards the entire system of their activity and its history of change. Then, the team was able to generate secondary artifacts as tools for ongoing analysis and reflection upon their work. In the competence laboratory, the team engaged itself in a form of collaborative activity of generalization, in which the team was using tertiary artifacts for reconstructing and retooling their methods of generalizing and learning at work. It is this new level of workplace learning that we expect will become increasingly important and in demand.

Note

1. The intervention as well as the collection and analysis of the data was carried out by M.A. Heli Ahonen.

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