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Reflective Design of Technology for Human Needs

Abstract: Inspired by an economic interpretation of the Faustus drama allegorically disclosing the 'alchemical' nature of modern economy, the paper presents a critical view on the development of technology as concomitant phenomenon of work practices with particular focus on manufacturing. It starts with a theoretical perspective on the dynamics of creating explicit propositional knowledge and its re-appropriation for practical use. This lays the ground for understanding how technical artefacts emerge from and, in turn, affect social practices. It further helps to understand the development of human reflective action competence and working capacity as most relevant forces of production in complex and dynamic market environments. These relationships are exemplified in some detail by looking at the problematic development and use of IT in manufacturing's value creating processes. The paper finally advocates reflective attitudes and evolutionary procedures as basic principles for designing useful and useable IT systems according to human needs and for protecting oneself from the Faustian omnipotence delusion of endless and effortless wealth creation.

Key words: Technological development, knowledge creation, knowledge appropriation, human reflective action competence, forces of production, information systems, manufacturing

1 Introduction: Faustus as Metaphorical Drama

According to the classical drama by J. W. Goethe, Faustus is a figure personifying the human drive for ceaseless activity, creative dynamics and visionary acting. In his excessive striving for knowledge and perpetuated creative activity, Faustus fails, however, to recognise natural bounds he tries to ultimately transcend by applying magic forces in which Mephisto effectively assists him. This assistance is based on a bet between the two according to which Mephisto is obliged to provide any of his powerful services as long as Faustus has not yet experienced 'the highest moment' he wants to last, i.e. the moment he has conquered time and transitoriness in his life activities (Coleridge 2007).

In his brilliant book entitled 'Money and Magic', the Swiss macroeconomist H. C. Binswanger (1994) presents an economic interpretation of the drama demonstrating the "alchemical" nature of modern economy. While metaphorically interpreting the original efforts of transforming lead into artificial gold as a symbol for breezingly creating unbounded value, the alchemical process is conceived of as continuation of demiurgical world creation by humans and seen as an attempt to overcome transitoriness by unlimited value creation through capital accumulation ceaselessly transforming things into money. While money as a product of the human mind thus deploys the fascination of endless and effortless proliferation, modern economy turns out to be continuing alchemy with other means. This economic interpretation of the drama is substantiated by the fact that Goethe served as a Minister of Finance to the Weimar court for more than ten years, a position in which he was well aware of the latest economic theories and practices of the time (e.g. the scene with Faustus and Mephisto at the emperor's court is written according to the money creation models of the Bank of England and John Law's experiment with the *Compagnie d'Occident* in France).

In reality, the economic process of value creation and capital accumulation is based on and embedded in metabolism with nature, however, and therefore equally depends on ceaseless technical progress in cunningly activating and using natural forces of production to continue or improve value creation. This is also reflected in the drama in which, towards its end, Faust perseveringly drives his business of gaining and meliorating land from the sea as the material basis for value creation beyond bounds. In this way the drama depicts the striving for knowledge creation and its transformation in technical progress as still another attempt to continue alchemy with different means. Culminating in the endeavour of creating *homunculus* as a form of artificial life, it promises again immortality to the creator. This appears as a perfect metaphor for the strong belief in technical progress and, in particular, for the persisting efforts of creating 'artificial intelligence' shaped as *"homunculus informaticus"* (Brödner 1997).

Inspired by these allegorical traits of the drama, the paper presents a critical view on the development of technology, in particular in manufacturing as the author's professional domain. It starts with a theoretical perspective on the development and nature of technology laying the ground for a better understanding how technical artefacts emerge from and, in turn, affect social practices and why illusionary visions of technical progress can so easily arise. Based on the author's long professional experience, these relationships are then exemplified in some detail by analysing the severe problems of productive development and use of IT in value creating processes of manufacturing. The paper finally constitutes reflexivity and evolutionary procedures as basic principles for designing useful and useable IT systems according to human needs and for guarding oneself against the omnipotence delusion of creating endless and effortless wealth in the 'unmanned factory'.

2 Dialectics of Development: The Nature of Technology

Looking back on the long history of technological development from the biface to the computer, the emergence of technical artefacts and their use appear as inescapable concomitant phenomena of social practices. The specifically human capacity of reflective action control allows human actors to attain some limited consciousness about their necessary object-related activities to commonly maintain and provide for their existence on the material basis of metabolism with nature.

Thanks to the intentional relationship to the surrounding world as well as enabled by the experience and action competence developed through socialisation and previous acting, humans are capable to assign meaning to things or events they encounter. By exploratory acting with objects at hand, they perceive the effects produced and conceive their functions offered, thus comprehending how to use them intentionally and purposefully. By remembering the action schemes and their recurring characteristics, classes or concepts of objects or events are being formed that can be shared by others with similar experiences. What is created as a concept by the cognitive capacity of the brain becomes a shared interpretative schema through joint acting. Hence, even exploratory and instrumental acting in dealing with things is of social nature: Things do exist only so far as they also exist for others. Concept formation and shared interpretative schemes thus constitute the human capacity to reflect on a shared social practice and to communicate with others about it. By acting and interacting with others in a shared world, humans "create" the things and themselves, seeing them as taken for granted (Mead 1903).

Through such specific efforts of reflecting on their common practice, by external or self-observation, social actors are able to form concepts and explicit propositional knowledge *about* what they are doing and how it is accomplished. This knowledge may then be externalised, communicated and shared in the form of linguistic propositions describing certain, although always constrained aspects of their practice or in the form of technical artifacts objectifying conceptually described abstract functions found in their practice. Technology thus proves to be a sister of language with concept formation as a common root.

Both propositional knowledge and functionalities of technical artefacts need to be appropriated and activated for effective use, however. The extensive processes of appropriation, i.e. learning and internalising to situatedly interpret propositional knowledge or an artefact's functionality and applying them for effective practical use again, will then produce a modified practice mostly including, however, unforeseen and unintended side effects that may become subject to further reflection.

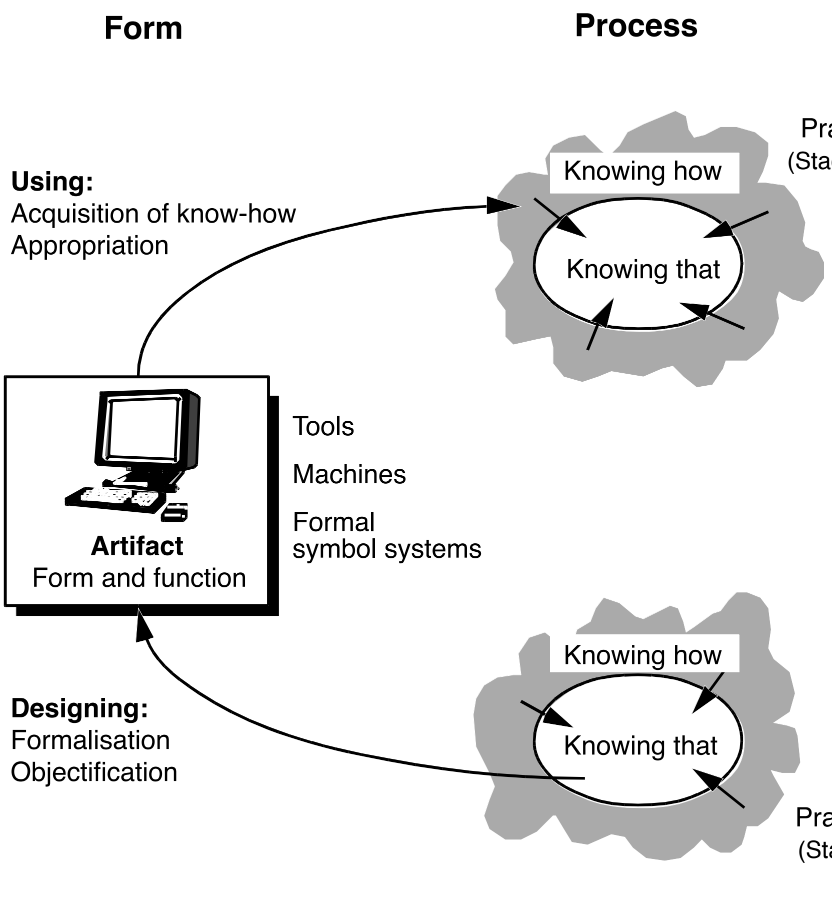

Fig. 1: Genesis and use of technical artefacts

In this way, technical artefacts emerge as objectified propositional knowledge about purposeful collective acting. They are, as such, used again as means for further acting. As "congealed knowledge" being inscribed in their functions and properties, the artefacts embody formal aspects or features of human practice, and as means of work to practical ends they set specific action requirements for effective use for which they must be appropriated again. Appropriation for knowledgeable and effective use thus constitutes a new practice, new ways of doing things. This spiral form of explicating practice into knowledge and internalising its results as enriched practice characterises cultural evolution (cf. fig. 1; Brödner 1997, 2009a).

Through appropriation, the objectified forms can be used as resources for further acting; they even enable or allow for new ways of acting, if interpreted differently. In the course of activating the artefacts for use, their affordances and action requirements evoke certain rules or routines of acting with them. These shared (but mostly unconscious) rules or routines – building the formative action context – enable the actors to appropriately interpret situations or facts as well as data, instructions, instruments or IT-artifacts, in short: to fluently act within the context of their social practice. Meaning, thus, is not a property of real things or events but assigned to them through common social practice.

The artefacts as resources together with the rules to deal with them, i.e. the attitudes, routines or patterns of thinking, acting, and sense making, thus constitute a social structure that facilitates and, at the same time, constrains collective acting ("duality of social structure"; Giddens 1984). What the actors in a social practice can imagine and which opportunities to act they see in a given situation therefore depends on the expressive forms they created as resources as well as on the action rules and routines they developed to deal with them. Hence, the actors are socially constructing their reality, however not of their own free will, but as prisoners of the conditions they have developed to enable and regulate their collective acting.

More generally stating, human actors own natural action competence and working capacity to intentionally and reasonably interfere with the world around them. With these specifically human forces of production allowing them to produce and reproduce their social life, they operate, however, embedded in a set of socially grown bodies of knowledge, organisational routines, technical artifacts, institutional arrangements, and governance structures handed down to them that altogether form a facilitating structure enabling and, at the same time, constraining their real acting. By reflecting and gaining new insight into their acting, its conditions and its effects, the interplay between the productive forces and the facilitating structure they are operating in expands action competence and working capacity that, in turn, may further develop the facilitating structure (cf. fig. 2).

This dialectical relationship between productive forces and the facilitating structure implies, however, that both can get into contradiction to each other. In particular, the further development of the first can be fettered by the conditions of the latter. This obviously applies to the present transition from an industrial to a knowledge-based society (Bell 1973, Drucker 1994). It is characterised by secular processes of scientification bringing about a substantial increase in professional knowledge work as indicated e.g. by growing numbers of highly educated knowledge workers (also called "symbol analysts", Reich 1991) or by continuous pervasion of work and value creation processes with IT as enabling and instrumental medium for knowledge work in manufacturing and service sectors (Soete 2001). These incidents increasingly induce knowledge-intensive value creation processes in which the creation, organisation, mediation or practical use of knowledge out-range by far the disposal of physical assets.

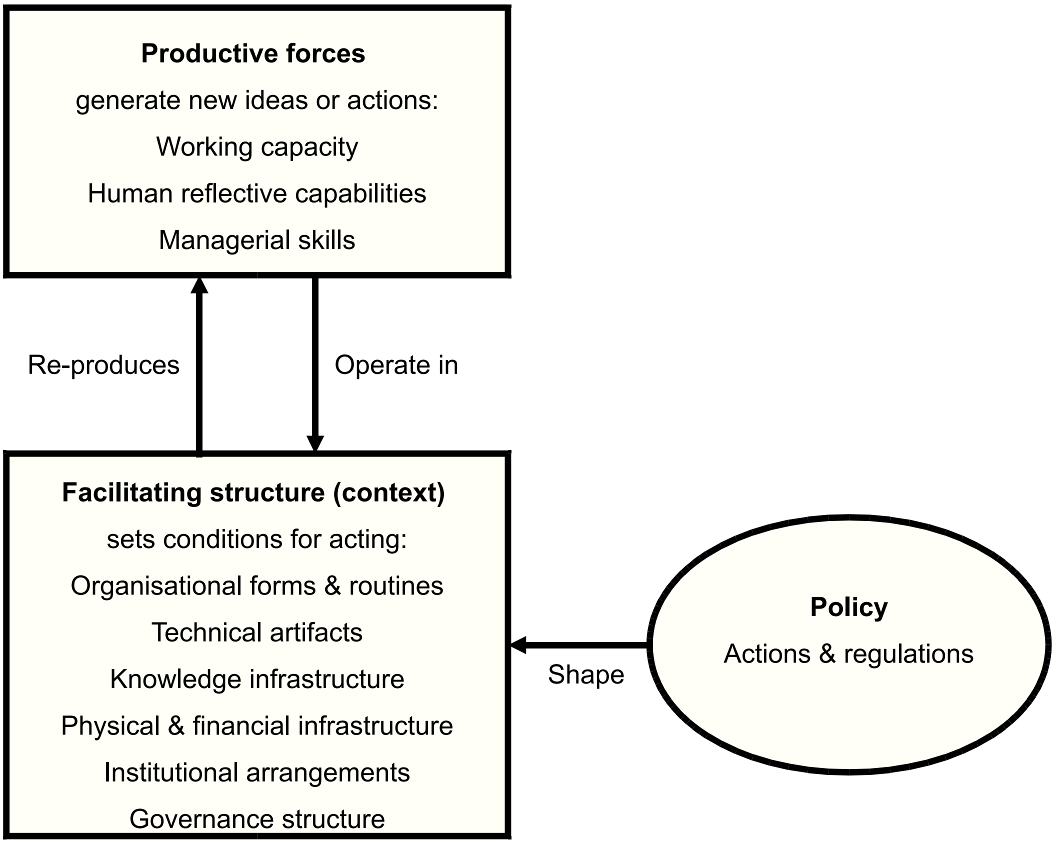

Fig. 2: The dialectics of human productive forces and facilitating structure

This transition, applying to service work and manufacturing alike, comes along with incisive structural changes in value creation processes due to particularities in dealing with knowledge. Knowledge is indeed a specific 'stuff' that defies its transformation as a commodity and requires specific working conditions and procedures. Taking up the conceptual distinction between explicit (propositional) and implicit (tacit) knowledge (dating from Polanyi 1966; cf. also Nonaka 1994), explicit knowledge depends, as outlined above, on the productive force of human reflective action competence or working capacity for being generated, enacted and put to effective use. While created by reflecting on and explicating knowledgeable action in practice, it is made practically effective only by appropriating it as 'actionable' knowledge – a learning process through which human working capacity is further enriched. The dynamics of explicating practical experience as propositional knowledge about social practices and of appropriating such knowledge as enriched action competence forms the basis on which working capacity, epitomising individual experiences, acquaintances and capabilities, spends itself and, at the same time, develops through working. As competently acting subjects, workers thus create their working capacity while affecting their objective environment (Brödner 2010).

Competence and knowledge prove to be 'generative resources' that grow rather than dissipate in use (Moldaschl 2005). While experiential and 'actionable' knowledge are bound to the bodily existence of individuals as owners and, therefore, cannot be disappropriated except through explication, explicit knowledge cannot be exchanged as commodity but shared with others only, except for being kept secret: "Sell me a cake and I have it, sell me the recipe and we both have it" (provided one knows how to make sense of the recipe). Moreover, non-knowledge likewise grows together with expanding bodies of propositional knowledge, due to the very nature of explicit knowledge that can contain only what its concepts comprise and ignore everything else. Knowledge work, therefore, longs for more knowledge work that, in contrast to material production, has no limits. Finally, the value of explicit knowledge is assessed by the quality it has for specific use rather than the effort it takes to create it.

In sum, all this indicates that the common knowledge management bias on generating codified knowledge frequently incorporated in IT systems is a management fetish (Nonaka & Takeuchi 1995). In contrast, the analysis of knowledge work suggests a necessary shift in perspective from *management*, i.e. the generation, organisation, and use of explicit propositional knowledge towards the development of collective 'actionable' knowledge and action competence. Instead of seeing „knowledge as a stable disposition" the focus needs to lay on „knowing as an ongoing social accomplishment, constituted and reconstituted as actors engage the world in practice" (Orlikowski 2002: 249). 'Actionable' knowledge or „knowing-in-practice" is comprehended as dynamic collective action competence in a changing environment that is deployed, enacted, and made effective as well as it is simultaneously being developed through shared organisational practices: „Knowledge is not something that people possess in their heads, but rather something that people do together" (Gherardi 2006: 1).

Consequently, knowledge-intensive value creation processes, characterised by creative processing of knowledge, continuous problem solving and permanent innovation, decisively depend on human working capacity, on 'actionable' knowledge, knowledge sharing and self-management, in order to productively cope with the complexity, dynamics and inevitable uncertainties of turbulent markets deriving from that. The tacit dimension of action competence, therefore, is of essential relevance for mastering these processes. According to its nature, knowledge sharing in work requires a high degree of autonomy, self-control, free interaction, and mutual appreciation: "In a knowledge economy everybody is a volunteer" (Drucker).

This need for autonomy in sharing knowledge gets, however, in sharp contrast to the imperatives of profitable capital accumulation. Ensuring the dominance of capital profitability in dealing with knowledge as a predominant economic resource thus constitutes a new transformation problem for managing knowledge work: "… the problem of labour process moves from 'How do we ensure that employees do as managers say?' to 'How do we ensure that employees realize the full fruits of their own expertise and ingenuity for the purposes of the organization?'" (Sewell 2005: 688).

The particularities of knowledge work and complex problem solving, the results of which are frequently based on co-operation and knowledge sharing rather than individual capabilities alone, induce radically new forms of work organisation. Complex problem solving and customer-oriented innovations in the context of turbulent markets typically call for *multifunctional teams* like e.g. in "concurrent engineering" (Brödner 2010), in software development or for "interactive value creation" across organisational borders (cf. "open innovation"; Reichwald & Piller 2006). This is also why *project work* for complex problem solving with multifunctional teams as well as *communities of practice* for object-related knowledge sharing fastly spread in and across organisations.

As knowledge work expands, due to the complexity, dynamics and uncertainties of markets and value creation processes, as it defies detailed planning and control, and as it requires a high degree of autonomy and reciprocity, it can no more be managed by traditional systems of command and control. Instead, the high yield requirements of capital accumulation need to be procured by new forms of *indirect contextual control* exposing knowledge workers to market forces or customer demands without any buffering effects on the part of management. Such a widely de-confined grasp of the individual working capacity in total brings knowledge workers in a situation, however, in which they are compelled to act as entrepreneurs of their own working capacity rather than being a workforce controlled by management. As "dependent independents" they need to self-manage their work, permanently put in jeopardy of failure and, hence, compelled to drive themselves to highest possible performance all the time (Glißmann & Peters 2001).

The contradicting working conditions connected with such indirect contextual control schemes and performance measurement systems frequently lead, however, to severe mental health and wellbeing risks ranging from psychosomatic disorders to burnout syndromes and impairment of family relations. Spreading like an epidemic, they have negative impacts on the performance of organisations and causes enormous costs for losses of knowledge, health care and early retirement. In an international study on workplace stress, these costs were estimated to accumulate to 3-4% of GDP in the EU (Gabriel & Liimatainen 2000; in addition, a large German health fund recently found that the burnout syndrome has yet increased by 80 % since 1999 leading to sickness leaves double the length of the average). Due to challenging tasks, wide action scope and ample opportunity to learn, knowledge workers, on one hand, typically experience autonomy and are highly motivated to do a good job. They always face, however, due to the context-dependent and unforeseeable course of events in knowledge work, a high risk of lacking resources to accomplish their tasks, on the other. Due to this mismatch between work demands and available resources, mental health risks or actual disorders tend to derogate or to wear out the human working capacity on which knowledge-intensive value creation processes so much depend (Brödner 2009b).

A second basic line of conflict (not being elaborated more deeply here, however) concerns existing intellectual property rights: They allow for keeping knowledge secret temporarily for private monopolistic use, although knowledge as a public good defies being treated as private property. Keeping knowledge private clearly hinders sharing and rapid diffusion of that knowledge as a prerequisite for further development and innovation processes. For productive use, knowledge must instead be treated as a public good according to the practices of open access, creative common licenses or open source software development. Generally assumed conditions for an optimal allocation of resources – perfect property rights and perfectly competitive markets – obviously do not apply to knowledge (Brödner 2003).

3 The 'alchemical' seduction: Dreaming of the 'unmanned factory'

The dialectics of developing forces of production, the dynamic interplay between explicit codified knowledge and implicit action competence, between working capacity and means of work (cf. fig. 1) can now be applied to manufacturing in more detail. In this perspective, the explication and objectification of experiences from work practices in the form of propositional knowledge and technical artifacts such as symbol systems, tools or machines constitute a necessary prerequisite for functional differentiation and division of labour in the social reproduction processes of living. Provided that such knowledge is generated and used to conceptualise whole value creation processes, they can be planned and divided into well-specified production tasks that in turn can be prescribed, co-ordinated and controlled by management disposing of that knowledge. Workers – being deprived of all means of production except their workforce – can then be forced to specialise for specific predefined working tasks, social interaction can be mediated by symbol systems, and tools can mediate working activities on specific objects. The result of a specific working process can become the object of another process or a tool for a third one as well.

Historically, the dynamics of industrial development started with the introduction of *horizontal division of labour* according to the principles of Adam Smith and Charles Babbage. The total working process of producing goods was divided into a sequence of numerous functionally specialised operations to which specialised workers were allocated using adapted tools. This effected an enormous increase of productivity and, at the same time, reduced the efforts for training workers – an advantage which was overlooked by Smith, but was later elaborated by Babbage as the so called "Babbage principle". Moreover, the horizontal division of labour was a necessary prerequisite for further accumulating explicit knowledge on production processes and working operations that then could be externalised and objectified in the form of mechanically driven manufacturing machinery. Babbage himself largely contributed to the explication and codification of production knowledge and he applied the principles of horizontal division of labour also to mental work – an almost unthinkable endeavour at his time that led him to the invention of the basic computer architecture. With his basic considerations of organising work and developing technology, he demonstrated that the principles of division of labour could be equally applied to physical as well as to mental work (Babbage 1835, Brödner 1990), which certainly was part of the scenario of the engineers at the peak of later days' versions of computerised manufacturing processes.

Despite the productivity improvements by the new forms of work organisation, attempts have been made to intensify work within these forms that, in turn, caused hidden counteractions of going slow by the workers, though. Focusing on this problem and based on his belief in human rationality, the founding father of modern work management Fredrik W. Taylor, developed a scientific approach for studying and designing work – Scientific Management – that would meet the requirements of both parties – management and workers – as it would increase the productivity of the individual and at the same time protect the workers from being overworked and worn out (Taylor 1911).

Ironically, precisely these two conditions have remained central problems in later applications of Taylor's ideas. On the basis of his scientific management principles, a huge body of knowledge and a whole system of methods and procedures (such as force exertion or time and motion studies etc.) have indeed been developed to design work such that an average working person could perform it throughout its working life without any health risks or impairments. Taylorism, thus, created working processes and conditions that, by intention and definition, are not intensive. At the end, even the unions accepted the model in principle, despite all opposition of workers and their representatives against the harsh forms of control. They learned to use it as an instrument for negotiating and controlling conditions of work. As Taylor has been the favourite hate object the last three decades, there has been little interest in acknowledging his pronounced concern for the welfare of the workers as a supplement to work rationalisation (cf. as a rare exception: Weisbord 1988).

The principles of Scientific Management by Taylor and his successors separated conception from implementation, thus creating a *vertical division of labour* as a basis and central guideline for designing manufacturing processes. Taylor's basic approach was to accumulate on management's side all relevant propositional or codified production knowledge needed to derive from that knowledge precise prescriptions of how to execute specified production tasks and of how long it should take to accomplish them. This separation of thinking from doing simultaneously created new forms of *direct command and control* of work by management and later on formed, together with the division of mental work according to Babbage, the basis for the bureaucratic forms of control as we know them from the rapidly growing corporations of mass production – bureaucracy literally meaning that the power is located in the management office.

With this conception of the scientifically determined "one best way" to accomplish working tasks and to produce goods he was deeply rooted in the rationalistic tradition of the West. This tradition is built on the far-reaching assumption that the world surrounding us is – at least in principle – fully comprehensible and describable in objective terms or by propositional or codified knowledge, and that, accordingly, human behaviour can finally be explained by the functioning of symbol processing machines. Provided that sufficient analytical effort is being dedicated, this perspective consequently envisages the full describability and controllability of production processes by means of data and algorithms, and, ultimately, the replacement of human experts by machines even in intellectual work. The alchemic dream of creating the 'unmanned factory', i.e. the everlasting and effortless production of commodities, capital and wealth, appeared to become reality. And in fact, throughout the 1980ies we experienced the so far last huge attempt of this kind, the implementation of knowledge-based and computer-integrated manufacturing systems (CIM) equipped with 'artificial intelligence'. Computer artifacts (integrating CNC machine tools, ERP and CADCAM systems with expert systems) were designed to increasingly replace the knowledge – and supposedly even the experience and skills – of human expert workers for being able to flexibly produce goods in a dynamic and uncertain market environment (Wiener 1954, Hunt 1989, Meyer 1990).

Despite huge intellectual and economic investments, this endeavour failed on fairly all levels, however. It failed intellectually, as it was built on the mistaken belief that meaning and intelligent behaviour can be produced through disembodied formal symbol processing based on and controlled by purely codified knowledge derived from a sufficiently complete conceptual mapping of the world. In contrast, meaning is, as outlined above, not an observable attribute of real world objects or events, however, it rather is created instead by interpreting the effects produced by living social actors when intentionally interacting with the surrounding world against the background of embodied past experiences and present intentions. This social constitution of meaning applies to instrumental acting with given objects and communicative interacting with others as well. As living or "autopoietic" organisms being embedded in and interacting with their environment, humans are, due to their reflective capabilities, able to form concepts and consciousness *about* their bodily existence and their interactions with the surrounding world including other actors. Their active minds thus recursively create meaning as ascribed features of the experienced reality through intentionally interacting with it. Hence, they do not passively mirror objective properties of reality but actively make sense of what they are doing and experiencing while interacting by means of conceiving the relationship between the intentions and effects of their acting. Assigning meaning by concept formation and test in practice thus is the reflective activity of making sense of intentionally interacting with the natural and social environment (Brödner 1997, 2007; cf. also Dreyfus 1979, Winograd & Flores 1986, Maturana & Varela 1992).

The CIM endeavour also failed economically, as it proved to be inferior to the high performance of competence-based production systems grown in the shadows of the CIM temples. They followed the "high road" of innovation and based their performance on co-operating skilled expert workers needed for and capable of putting codified knowledge and information technology to effective use, in particular with respect to flexibility and adaptability requirements of increasingly more complex and dynamic market environments (Brödner 1990, 2007). This result was not really a surprise, since it directly relates to the transition from industrial to knowledge-based production: In the course of developing Tayloristic production structures, more and more explicit propositional knowledge about manufacturing processes, gained by huge analytical efforts, was accumulated by management. This knowledge was used for designing and controlling complex work processes with simple tasks and sophisticated technology confronting the workers with an objective reality that disappropriated and devaluated their skills and competences wasting away over time. At the same time, this growing body of explicit manufacturing knowledge was used for continued product and process innovations that, in turn, created high demands on appropriating and adopting the new organisational schemes and innovative technical artefacts for practically effective use.

By reproducing bureaucratic forms and rules of organisation based on accumulation of codified knowledge and by shaping technology as a form of controlling work, the Taylor model was, without doubt, extremely successful under specific historical circumstances of societal development. As long as stable and transparent supply-oriented markets for mass products existed, as long as the products as well as the processes to produce them were simple and only few changes occurred over time, the rationalisation potentials inherent in the Tayloristic production system could be exploited to a large extent. The social inertia of its production structures caused difficulties, however, as soon as market conditions required more flexibility due to innovation and demand differentiation. In a hardly comprehensible, highly dynamic environment, with complex products and processes that are subject to various rapid changes as well, only living and learning systems can survive. They are crucially dependent on human skills, experience and knowledge, in particular on the ability to learn and the competence to act under uncertainty.

Conventional organisational structures in manufacturing based on horizontal and vertical division of labour are inappropriate to develop and comprehensively use these skills and competences, however. The Taylor model, in effect, was based on simplified working tasks with low skill requirements tied together and made effective by a complex organisation. Production knowledge and competence should not be relying on the skills and experiences of the workers but rather be embodied in the organisation, in the form of formal procedures, detailed instructions and codified knowledge being developed and maintained by a professional elite. Growing flexibility requirements to adapt to a changing environment as well as more demanding functional specifications for products and processes led to further differentiation of functions and more co-ordination effort and, hence, resulted in an even more complex, bureaucratic and inert organisation.

This trend could only be broken by a fundamental shift of perspective in organising work: By bringing together various related tasks, by reintegrating conception with implementation, and by introducing teamwork with direct task-related communication, complex jobs are created in a simplified organisation. Flexibility then is a result of continuous learning by skilled and competent workers; work no longer is the mere execution of prescribed operations but the unity of producing, reflecting, improving and learning – continuous improvement and innovation. The development of such new forms of work facilitating more autonomous knowledge sharing, learning and competence formation is undermined, however, by institutional settings and the new forms of indirect contextual control that regularly fail to provide necessary resources and thus impair the workers' health and wellbeing. In this way, the imperatives of capital accumulation as well as major components of the facilitating structure (cf. fig. 2) of the Taylor production regime, in particular selective education, that enabled the extraordinary growth of productivity and wealth, turn into fetters impeding the forces of production to further unfold.

4 Back to earth: Evolution of work and technology

It is an irony of technological development that exactly at the time when the attempts to accomplish CIM systems and to equip them with artificial intelligence failed almost completely, far-reaching innovations in information technology in the shape of networked personal computers, client server architecture and the worldwide web conquered the world. They provided a wide range of innovative "instrumental media" that – on the basis of representing work objects and means of work in the same digital form – could be used as tools for individual work and as means for communication and co-operation as well as for organising value creation processes in new ways. As such they formed the potential for an adequate technical infrastructure for organising knowledge work across spacial boundaries and for implementing competence-based production systems provided that organisations learned to appropriately adopt the functionalities offered for effective use.

Exactly this latter condition was not existent in most organisations, however. Captured in the old tracks of Tayloristic thinking, management frequently acted according to the strong believe in expecting high productivity gains through automating existing intellectual work, missing the opportunity to design new working structures by means of the new information technology instead – although there are a number of positive exceptions. On firm level this resulted in the empirically well investigated IT productivity paradox stating that organisational performance indicators such as profitability, productivity, lead-time or in-process inventory did not really improve despite continuing high IT investments. Highly computerised organisations often produce idle rather than active power. More recent studies elaborated the fact that there are, however, huge differences between firms depending on how much they engaged in complementary efforts for organisational change and competence development. Accordingly, a meta-study scrutinising 50 empirical investigations of the effects IT investments have on organisational productivity and performance came to the result „… that the wide range of performance of IT investments among different organizations can be explained by complementary investments in organizational capital such as decentralized decision-making systems, job training, and business process redesign. IT is not simply a tool for automating existing processes, but is more importantly an enabler of organizational changes that can lead to additional productivity gains‟ (Dedrick et al. 2003).

These interrelationships can be comprehended from a semiotic perspective on IT systems in organisations. This perspective is based on a triadic sign concept according to which a signifying object stands for the signified by virtue of the meaning assigned to this relationship. The working of computer artefacts involved in organisational sign processes can then be comprehended as a firm coupling of physical signal processing with social sign interpretation: Computer operations are internally constricted to pure signal processing fully determined by algorithms while these formal signal manipulating processes are externally initiated and interpreted in the course of purposeful and meaningful acting in the organisational context. Computer-mediated social interaction in organisational sign processes thus is inside the computer system characterised by causal determination of signal processing and externally by sense making interpretation of the signs associated with the signals. Inside the semiotic machine signal processing is determined by semiconductor physics and formal logic, while the same processes are subject to pragmatic interpretation outside, i.e. to the assignment of meaning in the use context of the organisation’s social interaction. Consequently, the social space of sign processes in organisational interaction is, while using the computer system, not being deserted at any time. Rather, certain procedural aspects of social interaction are being intentionally formalised and implemented within the computer system as a sequence of program instructions or “auto-operational form” (Floyd 2002; cf. Brödner 2009a).

Due to their semiotic nature and being embedded in organisational sign processes, computer artefacts become, through adoption and use, part of an organisation’s social structure that enables and, at the same time, constrains the course of collective acting. Technical artefacts at hand are being used by virtue of the meaning being assigned to the artefact’s functional affordances and use properties. By making sense of and effectively activating the artefact’s functions in use, specific regularities and use patterns will emerge. Through recurrent interaction with an artefact at hand, certain of the artefact's functions or properties become implicated in an ongoing process of structuring a social practice in which rules and routines of using them are being generated. As they begin to regularly structure action, they thus establish a changed social practice. The resulting recurrent social practice produces and reproduces a particular social structure of technology use (Orlikowski 2000). Consequently, the design and use of technical artefacts have to be regarded as integral part of a social system’s or organisation’s dynamics and, hence, as part of the development of organisational practices. In other words: Software is ‘orgware’ and launching an IT system means developing the organisation.

This is, however, an open collective learning process. Due to their semiotic nature and being derived from abstract, decontextualised knowledge, IT systems own high “interpretative flexibility”, always containing empty ‘slots’ that have to be filled in use through appropriation and “recontextualisation”, i.e. by interpreting and applying their functions appropriately to given situations. As the artefacts’ functions leave room for interpretation, their use value is constituted during application and they are, due to the scope of interpretation within the limits of their action requirements, open for diverse use practices.

A main consequence of the semiotic nature of computer artefacts and their embeddedness in sign processes of social interaction is the indispensable fact of "double hermeneutics" (Giddens 1984). This means that the object of observation, the social system, is not independent of the process of observing it. Rather, observation is a reflexive activity in the sense that the explicit knowledge gained about the social system, as well as the technical artefacts derived from that knowledge, become part of the system's resources and rules being changed by this. System designers do interpret features of a social system as object of observation, in which they themselves take part as observers. Since formalisation and model building, as central activities of IT system analysis and design are such acts of observation, they inevitably change the object of observation. The process of modelling itself is thus changing organisational sign processes as object of the analysis and modelling. This fact has been almost neglected so far in software engineering with fatal consequences: It is the basic reason for inevitably frequent requirement changes during systems implementation often deplored.

Remedy can only be achieved, if the design and implementation of IT systems is conceived of as *reflexive endeavour*. Project management and software engineering methodology must cope with this inescapable fact and, therefore, organise design and implementation processes in a reflective and evolutionary way with user participation on the basis of iteratively implemented, revised and improved versions of the system or its modules. This requires sound methods for software engineering and evolutionary project management that combine aspects of modular design, usable implementation, formative evaluation and collective learning in iterative development loops. The limited range of each loop will then facilitate to handle changing requirements and to confine the risks. Under the label of *agile development* practically tested methods and procedures have recently come up (e.g. "Scrum", originally developed for and used in design processes of mechanical engineering) that can effectively transpose such reflective and evolutionary approach (Beck 2001, Schwaber 2004).

Evolutionary project organisation with its strong user involvement further allows for combining the IT design (respectively configuration) efforts with the collective learning efforts for putting the system to effective use. While trying to make sense of a given version for accomplishing their working tasks, users simultaneously learn how to use the system and to generate further work-oriented requirements for an improved version – following the principle of learning by designing. If project management conceives and organises the joint evolutionary design, implementation and appropriation efforts in this way as integral part of organisational development, the organisation has a usable working system at its disposal at any time.

These efforts are, due to the system's embeddedness in the organisation's social relationships, always subject to micro politics and power plays, however. Project management, therefore, has to particularly take care that the actors involved transparently negotiate in order to productively integrate their different views and to balance their different interests. Rather than ignoring or fading these differences out, they need to be dealt with deliberately.

5 Concluding remarks: Healing the blindness

What can be concluded from analysing the developmental dialectics outlined, is first that continuing creation of technology is an anthropological constant of human social practices and as such is inescapable, second that this is always connected with unavoidable, but unintended side effects, and third that, therefore, it is necessary for survival to constantly reflect on emerging results of social practices in order to gain more insight how to dominate the conditions under which technology is developed and used. This particularly applies to the present situation in transition from industrial to knowledge-based societies. It is characterised by decelerated productivity growth, weakened innovation capacity and increasingly unequal wealth distribution in Europe (except for the Nordic countries) – contrary to common neoliberal dogmas of pushing prosperity. These contradictions indicate that the production of capital is beginning to be more important than production itself; that the high return demands of profitable capital accumulation undermine, by enforcing indirect contextual control and derogating educational efforts, the broad development of human action competence and working capacity; that institutional settings and governance structures of "shareholder value" creation fetter the productive forces urgently needed for further prosperity; that, in other words, processes of "creative destruction" tend to be damaged by destructed creativity.

Such unintended side effects of societal dynamics can, as has been demonstrated in relevant examples of organisational and technological development in manufacturing, only be overcome by reflective attitudes of the social actors. Consequently, the same reflective capabilities that create technology together with its risky effects need to be used to take corrective action. Above all, the reflective capabilities are specifically needed to dominate and control the direction of overall development, e.g. in the form of critical scientific analysis and of industrial democracy schemes that converts those concerned into participants. This appears to be the essence of "human use of human beings" (Wiener 1954).

Finally reconsidering the Faustus drama, Goethe had, being deeply rooted in humanistic traditions, a truly realistic view on the magical or 'alchemical' endeavours of Faustus and Mephisto: At the drama's end, he lets Faustus go blind and, when hearing shovel work, he lets him believe the workers are busy to build dams against the sea gaining new land for productive use as in Faustus' vision, while in fact they are digging his tomb (having lost his bet with Mephisto). This provides us with a perfect allegory for an uncontrolled, 'blind' progress and the demurgical delusion of everlasting effortless creation, be it in the form of bank money creation, artificial intelligence or the unmanned factory. From this we can learn that truly human endeavour must recognise instead the limits of knowledge as well as the unintended side effects of human acting. While acting, humans therefore always need to take a basically reflective attitude towards their own social practices in order to eventually be able to correct it.

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