Learning and Teaching in Socio-technical Environments

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Abstract: Computer supported learning environments can be analysed as socio-technical systems. New aspects of system theory, such as self-reference, autopoiesis, autonomy and contingency can be correlated with concepts of the research on social capital and social identity. This provides a basis to interpret empirical findings in the case of the practical usage of a learning environment and to propose measures of improvement. Ubiquitous self-description and continuous facilitation of communication processes can be considered as important success factors.

1. INTRODUCTION

The usage of information technology for teaching and learning not only supports these activities but also influences and forms their characteristics. In an increasing number of cases, learning processes and technical systems not only have a co-appearance but are highly interrelated. The result is a specific kind of socio-technical learning and teaching systems which have to be carefully understood to achieve a successful adaptation between organisational processes and technical design. In universities, various kinds of technical systems have to be taken into consideration such as interactive e-learning modules covering specific topics, platforms employed to store and provide access to traditional learning material via WWW, systems

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supporting collaborative learning, and applications which facilitate organisational tasks.These systems are interwoven with lectures, practising groups and seminars. Since these different types of technical support will be increasingly combined and embedded into appropriate organisational processes and didactical methods of teaching and learning, we assume that universities will become socio-technical systems where the use of technology is directly related to the characteristics of teaching and learning and vice versa.

This paper describes the key concepts which theoretically characterise socio-technical systems and are practically relevant for teaching and learning. The relevance of social identity and social capital for the development of communities as a success factor of computer supported collaborative learning is emphasised. The influence of these concepts for the development and use of technical systems in universities is illustrated through consideration of the collaborative learning environment KOLUMBUS. This not only covers a technical system but also organisational procedures and rules which are relevant to support collaborative learning.

The relevance of a socio-technical perspective is outlined by referring to empirical findings about the usage of KOLUMBUS. While KOLUMBUS is an example on the level of seminars, we conclude with a section which transposes our considerations and requirements on the level of the university as a whole.

2. THEORY OF SOCIO-TECHNICAL SYSTEMS

2.1 The terminology

The term socio-technical system is often used in its literal meaning simply referring to a combination of organisational, technical, educational and cultural structures and interactions. An historical consideration reveals the potential and the deficits of this approach. The term is linked to a tradition founded at the Tavistock Institute in the 1950s: Trist, Bamforth and their colleagues analysed the situation in the British coal mining industry where productivity had dropped after the introduction of new technology (Trist and Bamforth 1951). Their findings led them to conclude that the productivity of a working organisation not only depends on social aspects of work organisation but also on the well considered integration of the technical systems being used. They subsequently developed an elaborated method of analysis and intervention in working organisations - the so called socio-technical approach. This was adopted and further developed by Emery and

Thorsrud in the Norwegian industrial democracy project (Emery and Thorsud 1976).

In the 1960s and later it became an important aspect of their work to face the theory and practice of management with the relevance of the social aspects of work organisations and the fact that human co-operation cannot be controlled in the same way as machinery. It was only later that the socio-technical approach was transferred into the area of computer system application - for example by Enid Mumford (1995). She claims that the aim of socio-technical design is to give equal weight to social and technical issues when new work systems are being designed (Mumford 2000). Others, such as Eason (1988) also emphasised the aspect of organisational change. He states that a socio-technical system can be a subject of design activities and that the starting point of this design has to be a careful definition and analysis of the social system including people's work roles and their ways of co-operating.

These socio-technical approaches, as well as other concepts of systems thinking which take "soft" aspects into account (Checkland 1981), are all oriented towards open systems. The behaviour of open systems is influenced from outside and depends on the stimuli which occur in their environment. This focus implies several deficits. Most importantly it cannot explain the lack of causality between influences from outside and the reactions of a human individual or a social system, such as a company, a department or a class of students. The same deficit applies to the relationship between social systems which *produce* technology and those which *use* it. The interaction between processes of producing, introducing and using technology does not follow the pattern of cause and effect.

2.2 New approaches in system theory

To overcome these deficits it is sensible to refer to more recent concepts of systems theory developed with respect to living systems (Maturana and Varela 1987), self-referential and self-organising systems (von Foerster 1970), and neo-constructivism (von Glaserfeld 1984). Luhmann (1985) combined and integrated these concepts into a theory of social systems. This theory helps improve our understanding of socio-technical systems and our appreciation of the difference between social and technical structures.

The main difference is that cognitive or social systems are not only open - so they can interact with their environment - but are also closed. Thus the final selections of the system's behaviour depend exclusively on its own structure (Varela 1981). The reactions to influences from outside and the way the perceived behaviour of its environment is transformed into information processing or into operations are determined by the system's

own structure and not from outside. This phenomenon of referring exclusively to itself is described as self-reference (Luhmann 1993). It enables a system to behave autonomously. Autonomy does not imply that it is not related to its environment: the impulses from outside can initiate the selection between different alternatives. Typical examples are communication or teaching processes: a message in the course of a communicative process establishes a scope of expectable reactions on the part of the recipient, however the selection of the reaction depends exclusively on the recipient. This relationship between a message and the following reaction - for instance a question and an answer - can be described as "contingent" (Luhmann 1995; Parsons 1967). Contingency applies also to the relationship between the efforts of a teacher on the one hand and the development of a student's competence on the other.

The phenomenon that living, cognitive or social systems are self-dependent or self-referential is not self-evident since they could also be considered as a product of their environment. Maturana (1985) explains the possibility of self-reference by referring to the observation that living systems constantly produce themselves. This structural characteristic is called "autopoiesis": a network of interacting elements constantly produces the elements and interactions of which this network is built (Maturana 1985). An autopoietic system determines by itself which elements do or do not belong to it. Autopoiesis includes a continuous maintaining of the system's identity and its boundaries with the environment (Varela 1981). In the course of autopoiesis, the systems establish and reproduce their own rules of their functioning as well as the way they perceive and react to their environment. These thoughts also form the basis of constructivism (von Glaserfeld 1984) - how reality is perceived depends on the structure of the observing system and there are as many realities as there are observing systems. The concept of constructivism has increasing relevance for the analysis of teaching and learning processes and is related to a learning paradigm with two interesting characteristics:

"learning is an active process of constructing rather than acquiring knowledge and instruction is a process of supporting that construction rather than communicating knowledge." (Duffy and Cunningham 1996)

In contrast, the characteristics of technology must not be described by referring to contingency, self-reference or autopoiesis. A technical system is not a product of its own but is made and controlled from outside. Thus, it is determined from outside whether an element is part of the system or not. Technical systems serve purposes which do not lie within themselves but are assigned from other systems. The successful usage of technology requires

pre-defined and reliable input-output relations instead of a contingent relationship between the user's action and the technical system's reaction. Even in the case of so called "learning machines" a program determines how the machine learns and what kind of rules about the structure of its environment it can develop.

In the case of socio-technical systems, these two types of fundamentally different systems are combined and integrated. Technical systems are always a part of the environment of a social system, but, in the case of socio-technical systems, the interaction with the technical system is not coincidental but is systematically reproduced. We assume, in general and especially with respect to collaborative learning systems, that the following characteristics are decisive for a socio-technical system.

- Reciprocal indispensability: The technical system is as indispensable for the behaviour, the interactions and the autopoietic process of the socio-technical system as the communication processes of the social system.
- Reciprocal forming: The possible input-output relationships of the technical system have a forming influence on the communication structures of the social system and vice versa. Technical elements are an integral part of the socio-technical system. Their absence would affect the characteristics of the social system and would alter the process of its constant renewal.
- Ubiquitous self-description: The socio-technical system includes processes of describing itself. This self-description does not only identify the communication acts that make up the social system but also identifies relevant technical elements as integral parts. Self-description is partially represented as semantic artefacts which can also be found as representations displayed by the technical system.

2.3 Self-description

All three of these characteristics are indispensable. We consider the phenomenon of self-description needs special attention since it is not only an analytical category but also a matter of design. Luhmann (1995) states that social systems are self-referential and therefore include descriptions which are necessary to guide the continuous process of self-remaking or self-renewal. Self-descriptions can be found in different forms: as part of temporal communicative articulations and, consequently, as persistent semantic artefacts. Socio-technical systems can already incorporate several types of descriptions. On the one hand, the description of social-systems is encoded in conventions, in the verbal elements of a shared semantic system, a meaning system or even in written rules or laws. In organisational systems, co-ordination is a major issue that is dealt with by these descriptions. They

are also relevant to co-ordinate processes of collaborative learning. Technical systems are described by engineering artefacts. Computer systems in particular are described by software engineering oriented modelling methods or program code. Today both types of descriptions are separated, often not made explicit and hardly reflect each other. It is a matter of design to offer methods which support two requirements:

- The facilitation of integrated descriptions covering both technical and social aspects.
- The option to make these descriptions part of communication processes or technically stored and displayed representations.

The modelling method SeeMe (semi-structured, socio-technical modelling method) (Herrmann and Loser 1999), meets both requirements since it can handle contingency, incompleteness, and freedom of decision as well as well defined input-output relations.

We assume that self-description is of high relevance for the success of computer supported collaborative learning since the students need a basis to understand themselves as a learning community which has a certain social identity - even if their interactions are partially computer-mediated. The mediation offered by computers can both support and hinder the development of a (virtual) community's social identity. To obtain a better understanding of the relevance of social identity and its pre-conditions, it is important to refer to its relationship with the concepts of social capital (Putnam 2000; Fukuyama 1999) and communities of practice (Wenger 2000).

2.4 Self-reference in the context of social capital and communities of practice

We assume that collaborative learning cannot evolve and succeed without the building of a network, norms and trust - exactly the features of an organisation which are the essence of Putnam's social capital since they facilitate co-ordination and co-operation for mutual benefit. According to Wenger (2000) social capital as a result of trust is the basis for the development of communities. He connects the concept of social capital with the concept of social-identity, which he considers is indispensable for the existence of a community. The relevance of social-identity can be confirmed from the perspective of the theory of social systems (Luhmann 1995): social systems maintain their identity and their borders towards the environment by being self-referential. Wenger adds practical insights to this theoretical approach by describing how social-identity can be achieved or maintained: mutually experienced events, rituals and conventions contribute to social-identity as well as the engagement and the alignment of a community's

members and the evolution of their shared meaning system. We suggest self-description can also contribute to social-identity and illustrate this in the context of the collaborative learning environment KOLUMBUS.

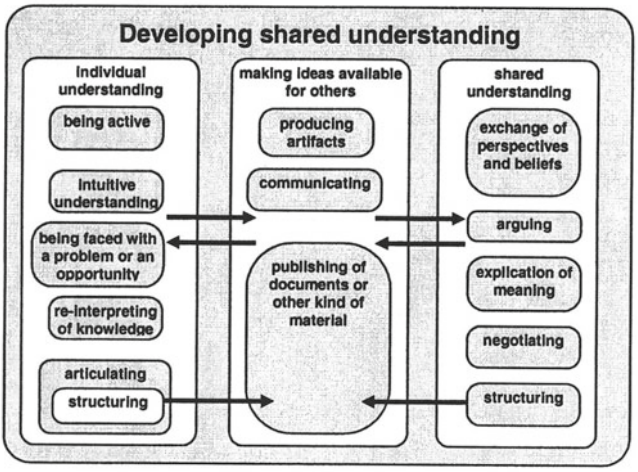

Figure 1. The interplay between individual and shared understanding

Social capital has different dimensions (van der Speck et al 2002) which can also be decisive for the success of collaborative learning:

- The structural dimension (Edvinson and Malone 1997): who can be reached, how and when.
- The relational dimension (Fukuyama 1999): personal and emotional bonding to one another.
- A cognitive dimension (Brown and Duguid): the shared understanding.

In the context of analysing and supporting collaborative learning, the relationship between shared understanding and shared meaning systems on the one hand and social capital and social-identity on the other is extremely relevant. This relationship influences the conditions for bridging the gap between individual understanding and shared understanding. Figure 1 describes some details of the interplay between individual and shared understanding and can serve as a basis for designing collaborative learning environments. Individual understanding is accompanied by human activities and is intuitive until the individual is confronted with a certain problem or an unusual opportunity. Both may lead to a re-interpretation of knowledge and to an articulation of parts of the knowledge - either to support a person's own reflection or the interaction with others. The interaction represents an attempt to achieve a better understanding in the course of re-interpreting knowledge. It is mostly based on communication but can include the

production of artefacts or the publishing of documents which do not need a pre-specified recipient. Making ideas available to others implies that differences may become apparent. This leads to an exchange and negotiation of perspectives, believes or arguments. Even the meaning system used for the discourse, can become a matter of re-interpretation and negotiation. All the activities in the diagram are relevant for the development of shared understanding. They have to be supported in a computer supported collaborative learning environment. In the context of computer mediation, the exchange of documents and the possibilities for giving them a meaningful structure gain relevance.

3. DESIGNING SOCIO-TECHNICAL SYSTEMS FOR COLLABORATIVE LEARNING

3.1 KOLUMBUS as an example for designing socio-technical systems

The collaborative learning environment KOLUMBUS was developed to support students during their work to achieve mutual results and shared understanding. It is a task-oriented system. The task is decisive. It should initiate a process of investigation and research and support the growth of shared understanding between students. We wished to offer a socio-technical system which supports the integration of collaborative research and learning. Therefore a technical system KOLUMBUS and a collaborative learning process "working with KOLUMBUS" were developed. They are described in "KOLUMBUS: Context-oriented communication support in a collaborative learning environment" later in this book. The core concept is to support articulation by offering the possibility to add annotations to elementary items of text or multi-media material. The annotations can be extended to a discussion thread and the recipients of communication acts can be selected by flexibly determining the access rights. For instance, a student can control whether he or she alone can read an annotation or whether the teacher or a selected group of students can read it.

KOLOMBUS was tested in a real seminar which is a mandatory part of the computer science program at the University of Dortmund. The task was to prepare a talk and a presentation to be given at a meeting of all 16 seminar participants. The students had to support each other by commenting their preparation material and to avoid overlapping between the different talks. Some of the empirical findings can be directly related to characteristics of socio-technical systems and the underlying theoretical concepts. The

experience with KOLUMBUS clearly shows the relevance of the aspects of socio-technical systems for the development of (collaborative) learning environments, particularly "supporting self description" and "(communicative) facilitation".

3.2 Supporting self-description

The model of the *KOLOMBUS-process* is a semantic artefact representing a part of the socio-technical system and thereby supporting its self-description. A derivative of this process model was used to instruct the students and to explain to them how the seminar is organised, what they were expected to do, and how the technical features of KOLUMBUS should be used.

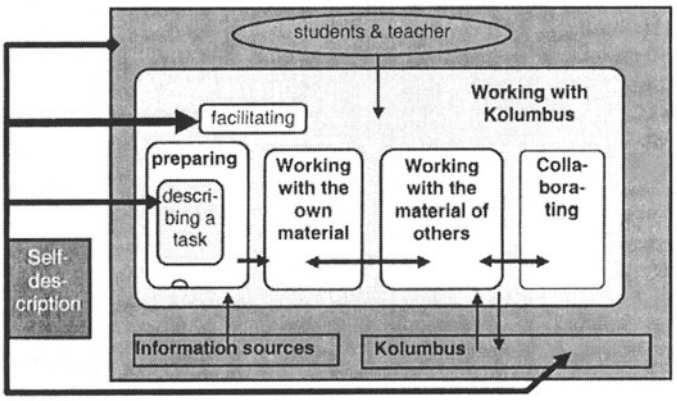

Figure 2. The description of the KOLOMBUS-process being a part of the process itself

Thus, a representation of the *KOLOMBUS-process* was part of the training and preparation of the seminar - both activities are elements of this process. This is a typical self-referential constellation. Furthermore, the model of the *KOLOMBUS-process* was not only a part of the communication course of the preparation but was also stored as a document in the KOLUMBUS database. This document was potentially present and usable for the participants during the whole *KOLOMBUS-process* and was available to be part of self-descriptive processes within the socio-technical system. In Figure 2 a simplified process model describes how a representation of the *KOLOMBUS-process* can be considered an entity which is an integral element of certain activities and the technical system itself. Beside the representation of the process, it is also crucial that the description of the underlying task (as the basis of the learning process) is permanently

accessible for the participants. Therefore, the task outline also serves as a self-description. It is available as content which is stored in the system and can be the subject of annotations.

Not only the abstract but also the concrete processes of their research and collaboration should be comprehensible for the participants. How an idea, a solution, or a discourse has evolved or how a mutual result has been achieved should all be documented. Additionally, the contributions and the interests of others and the development of their knowledge should be optionally comprehensible with the help of the system. This can be supported by awareness functionalities (Sohlenkamp and Chwelos 1994). They make the actions of others in computer-mediated environments more visible. Awareness of others' behaviour and expectations can be considered a pre-condition of the evolution of social relationships, social-identity and social capital.

3.3 Relevance of (communicative) facilitation

It is an important but not a surprising finding that the availability of a self-description document is not sufficient to guide the process of collaborative learning. A facilitation of the communication processes is needed to permanently give impulses and to focus the attention on the requirements of the *KOLOMBUS-process*. For example, the students had to be challenged to start with commenting on what others had written. The intended process has to be explained continuously. A facilitator has to give hints - what can happen next or on which contributions someone should react. The activity of facilitating is part of the collaborative process and therefore part of the *KOLOMBUS-process*. Consequently, it is part of the self-description and it uses this description by itself (Figure 2). During this process the interaction between students has to be stimulated. The availability of learning material and communication support on the World Wide Web makes the vision of learning-every-time-and-everywhere possible but by no means guarantees it is brought to reality.

The experience reveals that web-wide availability and ubiquitous opportunities to participate in the system are not sufficient. A facilitator has to provide well-directed stimulation and to propose phases of synchronisation during which the participants should interact concurrently. Furthermore, phases of intensive interaction and face-to-face communication are needed to promote the social relationships and to help to establish social capital. Both the teachers and students should have the possibility to play the role of a facilitator. This implies that they also have the opportunity to alter or adapt the *KOLOMBUS-process*. Consequently, they can consider their own interactions as elements which shape the system and contribute to its

permanent renewal in the sense of autopoiesis. The possibility of this kind of system adaptation can be a pre-condition for the adoption of the collaborative learning environment. The students have the opportunity to feel an integral part of a socio-technical teaching and learning system.

4. CONCLUSION: THE UNIVERSITY AS A SOCIO-TECHNICAL SYSTEM

The findings and principles, which refer to socio-technical systems, may be applied not only on the level of collaborative learning environments but also in the context of larger units. Increasingly, the university as a whole can be considered as a socio-technical system. Also on this level, appropriate organisational processes and technical means should improve the integration of the activities of learning, research and teaching. The organisational processes correspond with administration tasks such as configuring the access rights for users, procedures of registration, testing or assessment, and establishing services for multimedia support. A university has, on the one hand, to technically improve the possibilities for mobility and ubiquitous learning which is independent from limits of time and space. On the other hand it has to establish organisational procedures which guarantee that the members of the university have sufficient opportunities - by direct communication or meetings - to develop community-oriented social-identity and to build social capital. This needs facilitation, processes of mentoring, problem and project-orientated teaching, and continuous stimulation of communicative exchange. It also requires a proper integration of spatial and electronic functionality. Multimedia technology should not exclusively be available at isolated workplaces but should also be an integrated part of meeting facilities.

A university can be considered as a socio-technical system which consists of many sub-systems. All the departments, groups, centres or temporally built communities can also share the properties of socio-technical systems. Appropriate organisational procedures, training opportunities and technical means have to ensure that innovative solutions for teaching and learning are deployed to all these sub-units and that the process of innovation becomes continuous and sustainable. For instance, an e-learning module should not only be tested in one setting for one time, but should be adopted for many purposes if the test proves successful. This goal requires flexibility and adaptation. The process of integrating and adopting such modules in different sub-units of a university needs professional support and facilitation.

In the area of technical learning and teaching support, a university needs standards so that it can establish as a socio-technical system as a whole. On the other hand, flexibility is required to support the special needs of its sub-units. The balance between standardisation and flexibility is itself a matter of well integrated and adapted socio-technical processes. It has to share the main characteristics of indispensability of its components, reciprocal forming and ubiquitous self-description. Self-description on different levels supports self-reference, sustainability and social identity. It has to be completed by manifold forms of facilitated communication to initiate processes of change and to support the building of social capital.

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