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Information Systems as Socio-Technical or Sociomaterial Systems

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ABSTRACT

This paper considers the nature of the concept of an information system and particularly its basis as a socio-technical system. We argue that while socio-technical ideas have been heavily used within the discipline of Information Systems, the way in which an information system itself is socio-technical is quite poorly explained in such literature. We seek to address this by using a conceptual framework founded in organizational semiotics and systemics which directly locates an information system as mediating between activity systems on the one hand and technology systems on the other. We ground our discussion in a range of examples from different historical periods and cultures. This helps us demonstrate some of the universal features of information systems, whilst also demonstrating the central place of information systems in the sociomaterial practices of organizations.

Keywords

information systems, socio-technical systems, sociomaterial, universals

INTRODUCTION

In a series of editorials for the *European Journal of Information Systems*, Ray Paul has discussed a number of challenges facing Information Systems as a discipline and has proposed that part of the problem may lie in our discipline's lack of a clear conceptual framework upon which to build. He particularly raises the importance of defining the core concept of information system more clearly and distinguishing it from information technology on the one hand and business processes on the other (Paul, 2007a). The current paper seeks respond to this challenge in providing a clearer conceptualization of the socio-technical nature of an information system.

The idea of socio-technical systems has a long pedigree both generally (Emery and Trist, 1960) and within Information Systems (Mingers and Stowells, 1997) (Bostrom and Heinen, 1977) (Mumford, 2006). Socio-technical ideas particularly stimulated aspects of the participatory design movement (Clement and Van den Besselaer, 1993). However, and surprisingly, we would argue that the actual theoretical conceptualization of an information system as a socio-technical system is quite under-developed within this literature. We would further argue that information systems are central to understanding the sociomaterial nature of practice in organizations.

In an attempt to unpack the underlying features of information systems the author has been experimenting with a rather non-standard 'method' of work. First, in terms of empirical material we have been trying to collate, interpret and present cases from different time-periods and different cultures and use this material to formulate elements of a more encompassing systematics for the sense-making space referred to above. Second, on the side of theory we have looked to a range of topic areas, many of which are not particularly well-covered or considered within the Information Systems literature. This has helped form a composite conceptual framework which is tentatively proposed as a means of providing greater clarity to core concepts such as that of an information system. Third, we have engaged in a reflective cycle of using both the conceptual framework and the case material to ponder upon the essence of core concepts. Our aim has much in common with that of Mason et al (Mason et al., 1997) who argue for the importance of historical studies within the overall methodology of Information Systems. However, our aims in interpreting historical material are much broader from those detailed by Mason et al. From our position, historical cases are useful because they act as evidence of the universality of information representation, information systems and information technology across time, space and human cultures. We work from the premise that information systems are a natural consequence of the need for humans to communicate and coordinate activity.

Our method of exploration is therefore to utilise cases from the historical, anthropological and palaeontological evidence to seek to determine the essence of what we mean or perhaps should mean by these terms.

The particular aim of the current paper is to demonstrate one instance of the application of this 'method'. We introduce elements of the conceptual scheme referred to above and apply it to the question of the nature or essence of information systems. To help ground this discussion we examine a number of examples from cases pertaining to different historical periods and cultures, based in previous work of the author (Beynon-Davies, 2007; Beynon-Davies, 2009).

CONCEPTUAL FRAMEWORK

The conceptual framework which defines our sense-making space (Weick, 1995) is illustrated in figure 1. This uses the idea of signs and sign-systems to help systematize the relationship not only between data and information, but also between three types of system that serve to connect the social world with that of the technological. Hence, this layered model, which is sometimes referred to as the semiotic ladder, serves to represent the concept of information as necessarily a socio-technical phenomenon interposing between three different levels of system of interest: activity systems, information systems and ICT systems.

We would argue that a systematic definition of the concept of information must involve the concept of a sign (Pearson and Slamecka, 1983). Stamper (Stamper, 2001) defines a sign as being 'anything that 'conveys' information because it stands for something else within a community of users'. Steven Pinker (Pinker, 2001) argues that our cognitive makeup predisposes humans to be excellent manipulators of sign-systems; a sign-system being an organised collection of signs.

The study of signs and sign-systems is generally referred to as semiotics or semiology. Charles Morris (Morris, 1964) originally proposed three branches of semiotics – pragmatics, semantics and syntactics. In (Stamper, 1973) signs and sign-systems are considered in terms of four inter-dependent levels, layers or branches of semiotics: pragmatics, semantics, syntactics and empirics. These four layers serve to connect the social world on the one hand with the technical world on the other (see Figure 1) (Stamper, 2001).

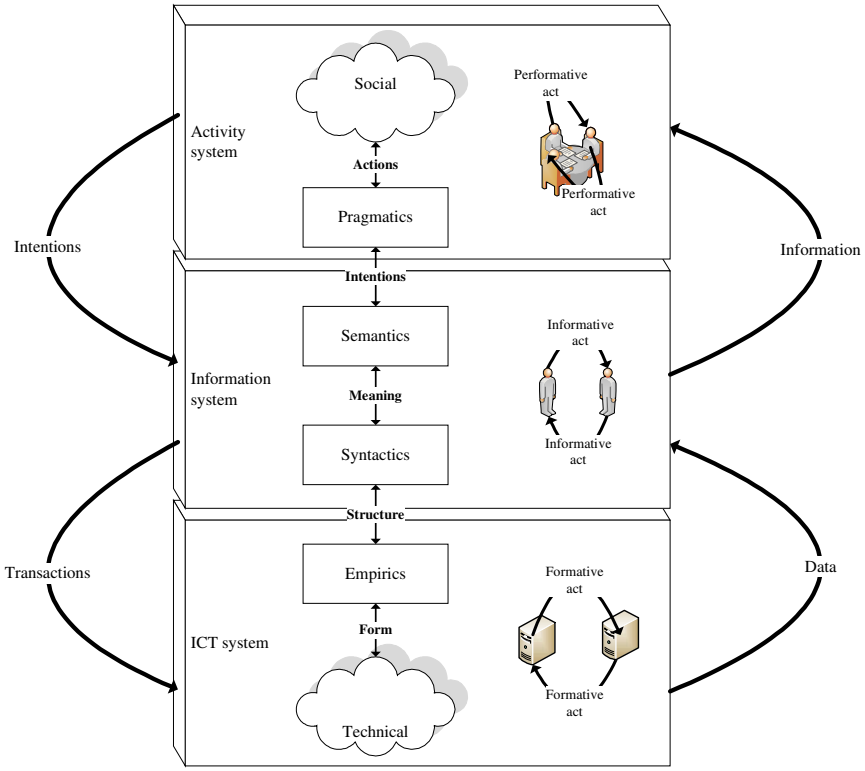

Figure 1. Conceptual framework

Pragmatics is concerned with the purpose or intentionality of a sign; semantics is concerned with the meaning of a sign; syntactics is concerned with the structure of a sign; empirics is concerned with the physical form or representation of a sign. Data cross the empirics and syntactics levels of signs and are concerned with the form and representation of symbols in storage and signal transmission. Information crosses the semantics and pragmatics levels of signs and is concerned with the meaning of symbols and their use within human action.

Consider an artifact used within the Andean civilisation of the Inca – the quipu. A quipu consists of an assemblage of cords of varying length and colour. Some 600 or so (Urton, 2003) examples of quipu survive and they typically vary from having a few cords to, in the largest case, being over 3 metres long and having over 2000 cords. A sketch of a quipu is provided in figure 2. There is evidence to suggest that quipu were used by the Inca as a key 'information technology' within coherent systems of information in support of activity systems within the Inca state. As such, quipu can be made sense of using the four levels of the semiotics ladder.

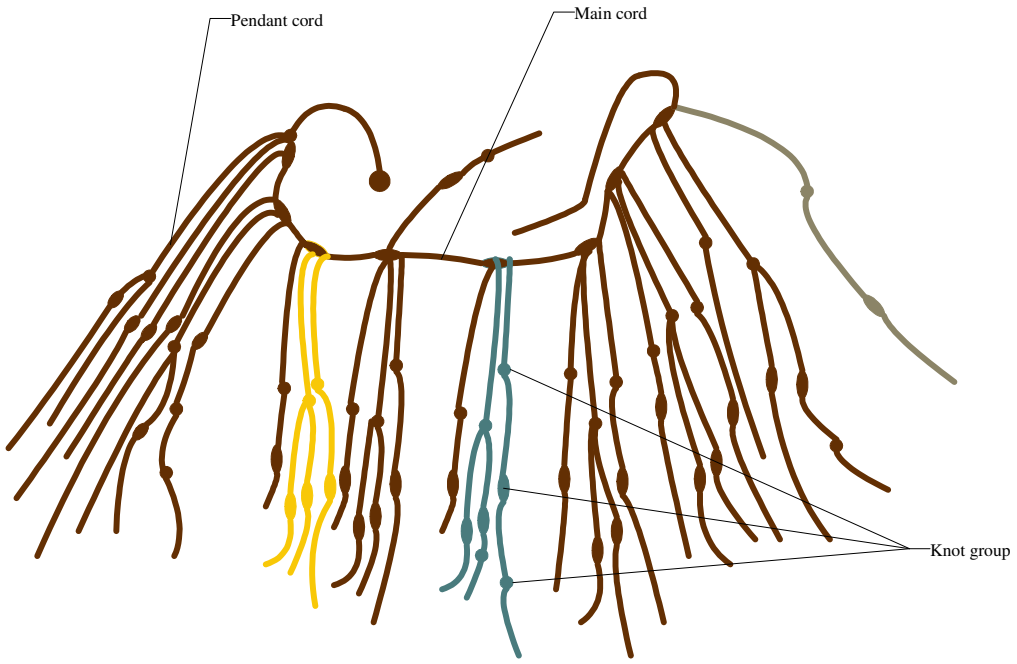

Figure 2. Sketch of a quipu

At the level of empirics, quipu can be analysed solely in terms of their methods of construction such as the construction of cords, the placement of cords, the construction of knots and the placement of knots. For example, the construction of cords in quipu varies in terms of the type of material used, the spin and ply of threads/cords, the colour of threads and the overall colour of cords.

At the level of syntactics, physical elements of quipu can be analysed as symbols and specified in terms of some data model (Tsitchizris and Lochovsky, 1982). Hence, there is evidence for the knot as being the fundamental symbolic element within quipu. The construction and positioning of knots relative to each other upon a pendant cord constituted a datum. A related collection of knots upon a cord – a knot group – constituted a data item. The collection of knots within a knot group serves to value the data item. A group of pendant cords would constitute a data element and the entire assemblage of cords within a quipu constituted a data structure.

At the level of semantics, the meaning of symbolic elements within quipu such as knot groups needs to be established. Evidence suggests that knot groups tied on pendant cords within certain quipu represent numbers to the base 10 (decimal) (Locke, 1923). Particular knot types such as single, figure of eight and long knots and their positioning upon pendant cords signify distinct numbers. Therefore, within this particular sign-system the relative placement of single knots on a cord could be used to represent units or multiples of ten. The closer the knot to the top of a cord: the higher the number. At the very top a single knot represented multiples of 10000, then 1000, then 100, then 10.

In terms of pragmatics, we would interpret quipu in terms of context: the information systems within which they were used and the activity systems they supported. A number of activity systems of the Inca Empire such as tax collection, the administration of workforces in the building of collective works and the distribution of goods within the Empire relied on an effective system of information flow. The main element of tribute paid to the Inca state was a labour tax in which each 'taxpayer' had to work a specified number of days each year on state projects such as road construction. Using the data recorded in quipu, 'accountants' in the Inca empire assessed levels of such tribute and assigned tasks to local workers.

THE CONCEPT OF AN INFORMATION SYSTEM

As the previous example demonstrates, signs take numerous forms and are used in various ways across distinct human cultures. We would argue that within organizations we are particularly interested in the way in which signs are used to express intentions, make decisions and generate action. This is clearly the realm of the social world. However, we are also interested in the relationship between signs and the physical world – particularly in the ways in which signs are embodied in 'technology'. Hence, we shall argue that an information system is a mediating construct between actions on the one hand and technology on the other. An information system is a form of communication system in which records represent and are processed as a form of social memory. Hence, an information system has many similarities to a semi-formal 'language' used to coordinate activity.

In the classic Shannon and Weaver model (Shannon, 1949), communication is a process that has the following characteristics (Figure 3). It involves two or more parties or agents. One or more of the parties in a communication process will be the sender with intentions to convey. The intentions of the sender will be expressed in a message using elements from a particular language; the language will have an agreed syntax. The message will be transmitted by the sender in terms of signals along some communication channel. One or more of the other parties will be a receiver. Receivers have the ability to interpret signals as a message in the sense that the meaning of the message becomes apparent.

The key elements of communication are therefore agents (senders and receivers), intentions, messages, language (with an agreed syntax and semantics), signals and communication channels. It is evident from this description that there is a clear relationship between the layers of the semiotic ladder discussed above and this classic model of the communication process.

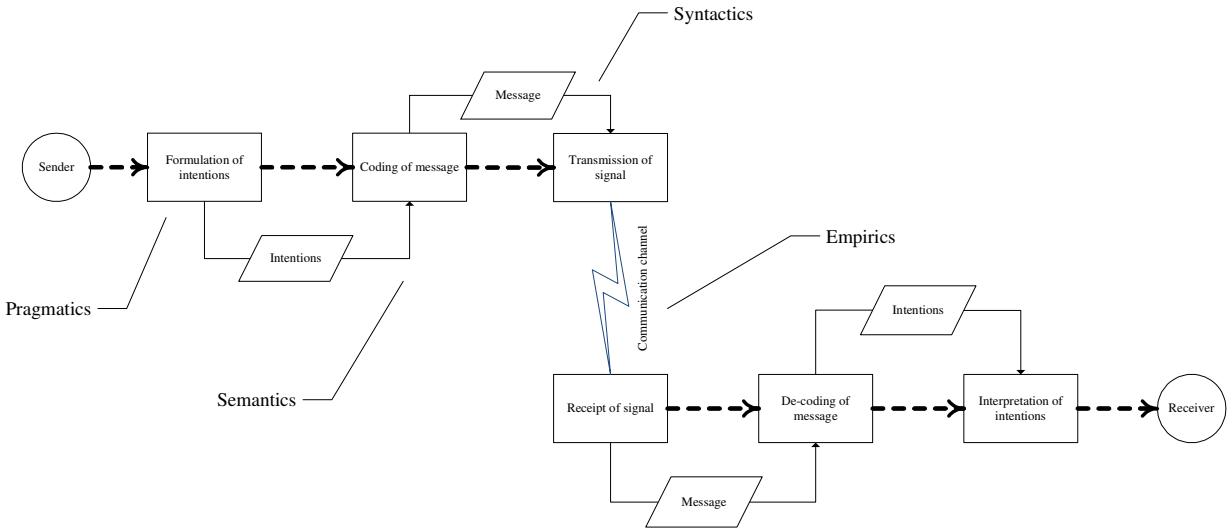

Figure 3. The process of communication

Communication normally exists within the context of some social situation. The social situation sets the context for the intentions conveyed (pragmatics) and the form in which communication takes place. In a communicative situation intentions are expressed through messages which comprise collections of inter-related signs taken from a language which is mutually understood by the agents involved in the communication. Mutual understanding implies that agents involved understand the chosen language in terms of its agreed syntax (syntactics) and semantics. The sender codes the message as symbolic elements of the language and sends the message as signals along some communication channel (empirics). The chosen communication channel will have inherent properties which determine outcomes such as the speed with which communication can take place

and over what distance. The actuating or effecting ability of a sender and the sensing ability of the receiver are critical to defining features of the process of communication.

Within conventional face-to-face human communication a given communication channel effectively corresponds to a sensing channel for symbols. A datum is equivalent to a set of symbols. Such symbols 'value' some data item. This begs the question of what is a symbol. A symbol is any physical characteristic of the world that can be modulated along some communication channel and hence used as a significant code within some domain.

The question of what is significant depends on both cognitive and social context. In other words, symbols are both individual (cognitive) and group (social) constructs. The range of features in the world that can be modulated is potentially infinite. Different cultures choose different aspects, features or facets of the world as significant. A finite set of facets derived from the infinite variety in the world is used to code a mutually agreed set of symbols necessary for communication.

Symbols as cognitive constructs consist of modulated aspects of the world dependent on the five human senses: sight, touch, smell, taste and hearing. The physical makeup of Homo sapiens determines what humans are capable of sensing: the range of phenomena that can be discriminated using a particular sense. This sets the cognitive background for what humans can use as symbols. There is thus a close relationship between symbols, signals and sensing. A symbol is an aspect of the world that can be modulated in a signal and hence can be communicated and sensed by actors in some communication.

Evidence seems to suggest that we all perceive the physical world in a similar manner but that 'language' is used to signify this world in different ways in different cultures. For instance, certain sounds and colours will have significance in particular cultures. Only certain of the sounds that a given human is capable of making will be used to form the phonemes of a given spoken language. In a similar manner, every natural language has a set of basic colour terms. English, for example, is usually seen to have eleven: black, white, red, green, blue, yellow, orange, purple, grey, brown and pink. Other languages have a different number. The Nez Percé (North America) has seven, Quechua (South America) has six, Ibo (Nigeria) has four and Jalé (New Guinea) has just two. However, this does not mean that speakers of Jalé only 'see' two colours. Instead, the complete visual colour spectrum is chunked up amongst the colour terms of the language.

Symbols as social constructs rely on a shared ontology amongst a group. The term universe of discourse (UoD), domain of discourse or ontology (Kishore et al., 2004) is used to describe the context within which a group of signs is used continually by a social group or groups. A shared ontology is a necessary condition for joint communication.

Shannon and Weaver's model was designed to focus on communication purely as an engineering problem. Not surprisingly, it has been seen as deficient as a model of human communication in a number of ways. First, it assumes the linear nature of communication (Burgoon et al., 1994). In contrast, human communication normally involves the use of feedback and is consequently transactional in nature. Human verbal communication, for instance, typically occurs in the form of dialogue, discourse or 'conversations'; in which the agents within the discourse adjust their messages in response to a history of previous messages conducted within a particular dialogue (Clark, 1996). Second, and as a consequence of its linear nature the Shannon and Weaver model tends to focus upon dyadic communication. Human communication in practice frequently occurs within and between groups of communicants. Third, and as a consequence of the group nature of human communication, the model illustrated in figure 3 also under-emphasises the role of records and record-keeping. When human communication occurs between more than two people and particularly when messages have to be transmitted across time and space, the persistent record is an essential feature of human communication.

Quipu are clear examples of the use of records within communication (Conklin, 2002). A given quipu was constructed by a specialist information worker known as a quipucamayuq. The quipu was then rolled up as a package and transported and delivered to a destination sometimes over thousands of miles distant by groups of runners known as chasqui. At its destination the quipu was unravelled and decoded by another quipucamayuq. Sometimes, such quipu were then stored as records of goods and people available to the Inca Empire.

Therefore, within the human sphere signs are used in a much more complex way than originally formulated within communication theory. This is because of the more sophisticated nature of human languages as sign systems and the importance of human interpretation to information representation and transmission using such languages. In its broadest sense the term language refers to an agreed system of signs used to convey messages between a set of communicative agents. Language is important because, as Stephen Pinker states, 'a common language connects the members of a community into an information-sharing network with formidable collective powers' (Pinker, 2001). This suggests an inherent relationship between information, communication, language and action.

Information systems are systems for using signs in the sense that they act as a communication medium between different people, sometimes spatially and temporally distant. It is therefore possible to consider the nature of an information system

from the point of view of language and action (Lyytinen, 1985). However, as we shall see, information systems are best described as semi-formal languages: some of their features are designed; some of their features emerge in continuous human interaction.

Using this conceptual lens, information systems can be seen to be semi-formal languages that are used to make decisions and as a consequence to create, control and maintain social action. On the one hand, an information system is tied to action. On the other hand, an information system is tied to a system of artifacts. The 'language' of some information system includes formal messages that create, control and maintain social interactions in an organisational context. Such messages not only serve to make statements about the world. They are also used to give orders, make promises or commitments, classify things etc.

In ancient Sumer, for instance, clay tokens were created as signs to symbolise units of goods accumulated in the collective surplus of the early cities (Schmandt-Bessarat, 1992). From the available archaeological evidence we can infer that such clay tokens were used as technology for recording a number of discrete acts of communication between creditors and debtors within the city-state. The act of creating a clay token and sealing a collection of such tokens within a clay envelope seems to have been used as a way of recording physical output of goods from one place and input into another place. It also appears to have been used to represent social relations of ownership and debt.

Within the language-action approach, the structure of some information system is considered in terms of 'speech acts' and conversations (Searle, 1970). The main idea is that engaging in some communication, such as uttering a sentence is the performance of an act. In the language-action tradition these acts of communication are referred to as speech acts, even though such acts are not restricted to the use of spoken language. The term speech act would also be taken to cover written texts and the use of other signs such as gestures, flags etc. The language-action tradition also refers to speakers and hearers as agents of a communication even though a communication may, for instance, be written. Therefore, to avoid confusion, we prefer to use the more encompassing terms: sender, receiver and communicative act.

Within the language-action tradition, communicative acts are seen as the basic unit of human communication and are categorised into numerous different types. The most important type of communicative act for the purpose of defining the nature of information systems is the illocutionary act: an intentional act of communication. Searle (Searle, 1975) identifies a number of different forms of illocutionary acts: assertives, directives, commissives, expressives and declaratives. Assertives are communicative acts that explain how things are in the world, such as reports and assertions. Directives are communicative acts that represent the senders' attempt to get a receiver to perform an action, such as requests, questions, commands and advice. Commissives are communicative acts that commit a speaker to some future course of action such as promises, oaths and threats. Expressives are communicative acts that represent the speakers' psychological state, feelings or emotions such as apologies, criticisms and congratulations. Finally, declaratives are communicative acts that aim to change the world through the communication itself, such as baptism, pronouncing someone husband and wife and sentencing a prisoner.

Illocutionary acts of communication normally occur in ordered sequences. These sequences are referred to as 'conversations', and have much in common with the idea of dialogues or a stream of discourse (Clark, 1996). Again, to avoid association solely with speech, these sequences are best referred to as communicative patterns. The major feature of such communicative patterns is their 'game-like' character. In other words, a particular communicative act creates the possibility of usually a limited range of communicative acts as response. For instance, in verbal discourse between two human actors a question (directive) normally elicits an answer, an assertion (assertive) is normally responded to with a statement of assent or disagreement, a statement of thanks (expressive) with an acknowledgement and an apology (expressive) with an acceptance.

In this view, information systems are seen as systems which create, maintain and fulfil communicative acts. Consider, for example, the case of the Warning Network (Holwell and Checkland, 1998b). This information system created within RAF's Fighter Command has been claimed to have contributed to victory in a decisive battle against the German Luftwaffe - the Battle of Britain – in 1940. The Warning Network could be interpreted as a number of inter-linked patterns of communication between actors within the different social groups involved in joint endeavour: radar operatives, observation corps operatives, filter room staff, operations room plotters, operations room controllers, aircraft pilots, and so on. Hence, elements of the communicative pattern from such an information system, includes communicative acts such as: a radar operator makes a statement of the expected strength, altitude, position and direction of an aircraft group to filter room staff (assertive); a plotter within the operations room confirms the last-known details of an aircraft group by plotting it on the plotting table (declarative); a group controller requests a sector controller to change the state of readiness of a particular squadron (directive); A sector controller confirms that a squadron has scrambled to a group controller (commissive). Each of these communicative acts can only occur at particular points in patterns of communication between relevant actors. Each communicative act also calls into play a limited number of other communicative acts in response.

FORMATIVE, INFORMATIVE AND PERFORMATIVE ACTS

The word information can be traced to the Latin verb Informare, meaning 'to shape', 'to form an idea of' or 'to describe' (Hobart and Schiffman, 1998). Dietz (Dietz, 2006) plays with the root of this verb (forma) and defines three sets of actions that we adapt for our purposes to correspond both with the three types of systems referred to above and to the layers of the semiotic ladder.

Information systems deal with informa – the content and meaning of signs. Informa therefore crosses the semantics and pragmatics levels of signs on the semiotic ladder. An information system is an example of a communication system and hence can be seen to consist of human actors engaging in communicative or informative acts (figure 1).

Forma is a term used to refer to the 'substance' that carries a sign. Forma therefore crosses the technical and empirics levels on the semiotic ladder. Within an information system much communication is stored, manipulated and transmitted via records. Records are data structures or symbol structures and storage, manipulation and transmission are all types of formative or data acts. Humans utilise formative acts and the records they act upon to extend the reach of their communicative acts across time and space, as well as between multiple actors. Hence, any 'formative' technology falls within this intension including Sumerian clay tokens, Inca quipu, the Hollerith Electric Tabulator and the modern digital computer.

The purpose of informative acts is to ensure coordination of activities. Performa is used to refer to the use of communication within 'performance' - individual and social action. Acts of production or performative acts correspond to the 'work' of people in collective interaction. Activity systems therefore consist of recurring patterns of performative acts.

The linkage between an information system and an ICT system occurs through the concept of a transaction. Associated with production or performative acts within activity systems is a corresponding flow of communicative or informative acts. These communicative acts generate transactions that record coherent units of activity, typically events within some activity system or between activity systems. Such transactions typically write to, delete, update or read from the records of some ICT system.

The purposes of human agents engaging in some activity system are encoded as intentions within the communicative acts of some information system. These intentions are also decoded in a two-part process which involves reading data from the ICT system and using information from the corresponding information system in support of decision-making and action.

In essence, the idea of the distinction between data (formative) acts, communicative (informative) acts and production (performative) acts is a convenient division to highlight the different roles associated with the more encompassing concept of a sign act. A sign act has intent (pragmatics), expresses meaning (semantics), has structure (syntactics) and has a physical representation (empirics). As such, a given sign act bridges between the social world (activity system) and the technical world (ICT system) through the mediating realm of human communication (information system).

Therefore, a sign act encompasses three inter-related forms of act which position themselves against the three inter-related forms of system illustrated in figure 1. Such patterns serve to define such systems. Patterns of performative acts occur within an activity system. Patterns of informative acts occur within an information system. Patterns of formative acts occur in the realm of an information technology system. Such patterns serve to enact models of the 'world' which enable humans to organise their actions in relation to such models. Hence, an information system can be seen as a 'model' of its activity system. In turn an information technology system can be seen to act as a 'model' of its encompassing information system.

CONCLUSION

In this paper we have introduced a conceptual framework based around the concept of a sign and sign-systems. This framework is inherently socio-technical in form and as such helps to provide a clearer sense conceptualization of the nature of information systems. We agree with Paul (Paul, 2007a) that information systems are distinct from information technology on the one hand and systems of activity on the other. However, the true nature of an information system cannot be understood without reference both to artifacts and activity. This is because of the mediating position of an information system as a socio-technical system.

Orlikowski (Orlikowski, 2007) has recently made claim for the sociomaterial nature of organizational practices. She argues that '…every organisational practice is always bound with materiality. Materiality is not an incidental or intermittent aspect of organisational life; it is integral to it.' This means that, '…the social and the material are constitutively entangled in everyday life. A position of constitutive entanglement does not privilege either humans or technology (in one-way interactions), nor does it link them through a form of mutual reciprocation (in two-way interactions). Instead, the social and material are considered to be inextricably linked – there is no social that is not also material, and no material that is not also social.' The conceptual framework discussed in this paper supports Orlikowski's contention. However, the precise nature of the sociomaterial is left unexplained by Orlikowski. We argue that the conception of information systems described offers a

way of understanding how the sociomaterial works and what it tells us in terms of good design. The consequence of this is that information systems can only be understood and studied as sociomaterial constructs and as a consequence must be designed in sociomaterial terms.

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