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Understanding collaborative learning activities in an information ecology: A distributed cognition account

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ABSTRACT

Collaborative learning encloses a diversity of activities, interactions, and practices. Thus, designing a learning environment, potentially enhanced with technology, to support collaborative learning, is not an easy task. Using an in-class exploration involving four multidisciplinary teams, this research seeks to understand collaborative design activities within "InfoSpace" – an information ecology. That is, a collocated space enriched with a multiple interlinked heterogeneous technologies. The aim of the study is to explore how an information ecology works as an integrated cognitive system, through the lenses of distributed cognition. Through the analysis we constructed a detailed account of the information flow, physical layout and artefact models. We claim that distributed cognition framework can provide a lens for understanding interactions among learners, tasks, and tools in collocated technology enhanced learning environments. Furthermore, the analysis provides valuable insights on how the design of the information ecology supports collaboration and coordination.

1. Introduction

The idea of Distributed Cognition (DC) is not new (Cole & Engeström, 1993). According to Hutchins (1995), cognition cannot be tamed within the boundaries of an individual, but researchers should expand the unit of analysis to include the surrounding environment. As a conceptual framework, DC can support the process of understanding complex and collaborative activities, particularly when dealing with technical equipment. It has been proven ideal for shedding some light to interdependencies between individuals and artefacts within collaborative environments where physical presence and technology played a significant role (Furniss, 2004; Hansen & Lyytinen, 2009).

Meanwhile, as technology progresses we are no longer tethered in front of a single screen and information technologies are increasingly used to support collaborative activities. Rather, as envisioned by Weiser (1999), ubiquitous computing is a reality in most collaborative working environments. Nardi and O'Day (1999) explained that an "information ecology" is a local environment enriched with multiple heterogeneous technologies, such as personal computers, handheld devices, interactive screens, which are interlinked as a unified system. Within an information ecology there are different tools and thus, individuals may act in different ways to complete a task. Therefore, the possibilities of combining information technologies in an information ecology are endless.

Yet, information ecologies may perform differently with different teams and collaboration styles, highlighting the importance of understanding specific group dynamics and contexts. When it comes to collaborative learning activities in a classroom setting, as team-members work together with a particular goal in mind, several tasks run at the same time and each team member may acquire a different way of performing a task. In the case of software design teams, one of the most salient problems is the existence of breakdowns in coordination and collaboration (Curtis, Krasner, & Iscoe, 1988). As various technologies coexist in the workspace, coordination and collaboration may become even more complex (Kaplan & Seebeck, 2001). Thus, designing a learning environment for collaborative design activities, potentially enhanced with technology, to support the diversity and complexity of all types of interactions and practices, is not an easy task.

Salomon (1992) argued that the design and integration of new technologies in classroom activities cannot be studied independently of the classroom environment. Moreover, Nardi and O'Day (1999) explained that it is important to understand the interrelations of people, tools and practices in a physical workspace, so called an "information ecology". Therefore, the design of effective information ecologies requires a deep understanding of the complex relations and interactions between collaborators and the

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multiple information technologies. That is, answering questions such as: How the information ecology allows the design group to coordinate their actions? How awareness is distributed within the group when working with multiple technologies? How each one of the technologies in the ecology supports coordination and collaboration of learning activities?

The current investigation was conducted through an in-class investigation of four software design teams. The process involved the analysis of the information ecology – called InfoSpace – in three aspects of distributed cognition; physical, information flow and artefact (Furniss & Blandford, 2006). The analysis sought to address two research directions:

– Whether distributed cognition is particularly well suited as a conceptual framework to study collaborative design activities within an information ecology.
– How distributed cognition supported reasoning and what kind of insights can it lead to in terms of the design of an information ecology for collaborative activities?

We start by covering related theoretical and technical background and continue with the analysis of our empirical investigation. The paper concludes with a discussion of key-findings, limitations and insights of this work for future directions.

2. Background

2.1. Distributed cognition

Distributed cognition is a conceptual framework for analyzing cognition in a distributed account (Hutchins, 1995). While traditional views restrict cognition within the individual, Hollan, Hutchins, and Kirsch (2000) indicate that distributed cognition considers a collaborative activity taking place across individuals, artefacts and internal or external representations, as one cognitive system. Authors continue by establishing the importance of understanding the distributions of cognitive processes in order to design effective human–computer interactions. In the areas of HCI and CSCW, distributed cognition has been found an effective framework for understanding interdependencies and breakdowns within collaborative activities (Furniss, 2004; Halverson, 2002). To date, researchers in these areas have focused on understanding cognitive systems of safety critical environments, in aviation such as air traffic control (Halverson, 1995), and airline cockpits (Hutchins & Klausen, 1996), or healthcare such as intensive care units (Rajkomar & Blandford, 2012) and emergency departments (Cohen, Blatter, Almeida, Shortliffe, & Patel, 2006).

In the case of software design teams, one of the most salient problems is the existence of breakdowns in coordination and collaboration (Curtis et al., 1988), thus distributed cognition was ideal to understand collaborative practices and breakdowns. Sharp and Robinson (2008) developed a distributed cognition account of four mature XP (extreme programming) teams, pinpointing how mediating artefacts (e.g. the Wall, story cards) supported coordination and collaboration. Hansen and Lyytinen (2009) drew on distributed cognition framework to elaborate on the trend of distributing knowledge during a software requirements process. Their work was based on a field study within an information system development workspace. In an experimental study, Mangalaraj, Nerur, Mahapatra, and Price (2014) involved software practitioners examining mechanisms for improving the software design process building on the foundation of distributed cognition. Therefore, researchers verified the complexity of collaborative tasks within software and product design teams, recognizing the need to understand cognitive processes distributed in the broader cognitive system.

Even though Salomon (1992) argued that the design and integration of new technologies in learning activities cannot be studied independently of the classroom environment, less attention has been paid in learning environments. In their study, Valanides and Angeli (2008) take a distributed cognition perspective for collaborative learning in dyads in an elementary school classroom. Authors claim that in order to best design technology for children, individual cognition must be allowed to be distributed across the wider cognitive system such as the teacher or the rest of the classroom. Schrire (2004) drew on distributed cognition to examine asynchronous distance learning technologies. Either in distance learning or in-class technologies, distributed cognition was recommended as a conceptual framework for a careful design of educational tools.

2.2. Distributed Cognition for Teamwork (DiCoT)

In order to analyze and understand our data from the distributed cognition lenses, we adopted the DiCoT methodology introduced by Blandford and Furniss (2006). This methodology draws together representations adapted from Contextual Design (Beyer & Holtzblatt, 1998) and principles central to DC. This methodology includes 22 principles that can be loosely classified in three major themes; physical layout, information flow, and artefacts, constructing the three major models of DiCoT (Furniss & Blandford, 2006). A fourth group emerged as "Others", grouping cultural and social principles that could not be encapsulated within the previous models. DiCoT models and corresponding principles are enumerated and described in details in Table 1.

The physical model relates to the physical organization of collaborative activities and covers all aspects to working which have a physical layout component. The focus of this model are factors that influence the way a system performs at a physical level, such as situation awareness, naturalness, bodily movements. Depending on the purpose of the analysis, the focus can be differ-

Table 1
DiCoT models and corresponding principles.

Physical layout	
1	Space and cognition: Space as a medium of supporting cognition during an activity
2	Perceptual: Spatial representations supporting cognition
3	Naturalness: Each representation match the features of that which it represents
4	Subtle bodily supports: How bodily actions are used to support activity
5	Situation awareness: How are people kept informed of the activity
6	Horizon of observation: What can be seen or heard by a person
7	Arrangement of equipment: Physical arrangement affecting access to information
Information flow	
8	Information movement: Mechanisms used to move information
9	Information transformation: How information is transformed in the system
10	Information hub: Central point of information flow and decisions
11	Buffering: Hold up information until it can be processed
12	Communication bandwidth: Richness of information during communication
13	Informal and formal communication: Identifying the importance of informal communication channels
14	Behavioral trigger factors: Individuals act in response to certain behavior
Artefacts	
15	Mediating artefacts: Elements used to fulfill an activity within the system
16	Creating scaffolding: How people use the environment to support their actions
17	Representation-goal parity: How close is the representation of current and goal state by artefacts
18	Coordination of resources: Plans, goals, history, etc. and their coordination to support cognition