The situated effects of awareness in distributed collaborative learning: Interactive 3D an example

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Abstract: Recent research in CSCL (Computer Supported Collaborative Learning) and CSCW (Computer Supported Co-operative Work) has provided insights into how various forms of awareness information should be computer supported to enable collaboration in distributed environments. Based on an understanding of learning as mediated by social interaction and artefacts (such as various forms of information and communication technologies), we argue that the effects of task and workspace awareness are highly situated with respect to collaborative knowledge construction. Some issues from this line of consideration are illustrated by examples gathered from designs of a distributed interactive 3D application.

Introduction

The awareness usually afforded in physical collaborative learning environments allows learners to implicitly maintain information about the others' interactions with common problem areas and corresponding tasks. If two learners are co-located they cannot help see, hear and perhaps even feel the presence and actions of the other. In distributed collaborative learning environments, where collaboratively oriented activities are mediated by various forms of information and communication technologies (ICT), these abilities are greatly reduced. The actions of the others can take place in deafening silence and their actions can almost be invisible. As a result, collaboratively oriented activities such as negotiation of meaning, creation of joint understanding, and division of labour and responsibility require meta-communicative actions for maintaining certain cognitive and collective effects of the distributed collaboration (Fjuk & Dirckinck-Holmfeld, 1997).

Awareness has become a focus in computer systems designs to reduce the meta-communicative efforts needed to collaborate across physical distances and in computer-mediated environments (e.g., Gaver, 1991; Dourish & Bellotti, 1992; Palfreyman & Rodden, 1996; Gutwin et al, 1995; Gutwin et al, 1996). Gaver (1991) underlines the importance of supporting awareness information to help actors to shift from working alone to working together. For example, Dourish & Bellotti (1992) connects this issue to shared workspaces and defines awareness as "an understanding of the activities of others, which provides a context for own activity" (ibid. p. 107). They argue that awareness information should be *passively collected* and *distributed* rather than explicitly provided by the actors through meta-communicative activities. Moreover, Gutwin et al. understand workspace awareness as "the up-to-the-minute knowledge about other students' interactions" and proclaim that such information plays an "integral part in how well an environment creates opportunities for collaborative learning" (Gutwin et al, 1995, p. 147). With references to the pedagogical aspects of problem solving and critical thinking Newman (1996) argues that up-to-minute information about co-learners' interactions has little to do with learning and knowledge construction. Computer systems that support workspace oriented awareness, he continues, are tools designed for routine work and for making efficient workflow possible, and "problem-solving becomes more important than routine work and effective critical thinking counts for more than efficient workflow" (Ibid.).

In this paper, we support Newman's line of thinking and argue that the effects of awareness information are situated according to what kind of social interactions we are talking about and the context specific conditions of ICT-based artefacts. The core arguments of the discussion are illustrated by examples gathered from designs of an *interactive 3D application.* The paper is first and foremost a theoretical contribution to a discussion concerning the effects of awareness information with respect to collaborative learning. Second, it is a contribution to the educational debate on 3D and collaborative learning. Distributed interactive 3D applications have been used to a limited extent as mediators in collaborative learning probably because the character of this kind of ICT has yet to be defined (Youngblut, 1998). There exist few in-depth studies that discuss the potential learning effects of collaboration through interactive 3D (ibid.).

The structure of the paper is as follows: In section 2, we specify our theoretical position of collaborative learning. In section 3, we discuss issues of awareness information with respect to certain conditions of collaborative learning. In section 4, we operationalise the theory with respect to distributed interactive 3D, and how the operationalisation was maintained in designs. Section 5, concludes the paper and addresses activities for further work.

Learning through genuine interdependence

Based on Vygotskian theory (e.g., Vygotsky, 1978) concerning the way collaboration contributes to cognitive changes and knowledge construction, learning is situated in social interaction and context specific conditions (Cole & Engeström, 1993). The learners are *interdependent* in the sense that there are positive cognitive effects in drawing on each other's knowledge through an intellectual partnership as well as through sharing of resources and artefacts (such as for example various forms of ICT-based solutions). Based on this theoretical heritage it becomes unreasonable to separate knowledge construction from the socially and artefact mediated context. Moreover, artefacts themselves are socially and contextually situated, carrying hidden assumptions developed into their design, and determine what can be carried out when, in what form and for what purpose (Leontjev, 1983). Thus, the role of artefacts is not limited to transmission of operational aspects of human interaction. The artefacts also shape the goals of the actors using them (Kaptelinin, 1996).

Salomon's (1992) work raises strong issues regarding the role of ICT-based artefacts in collaboration and knowledge construction. This becomes especially evident when he proclaims a difference between two kinds of desired effects, that is, *effects with* ICT and/or collaborating peers, and *effects of* these. Concerning the former, the *effects with*, are the changes or results afforded during the use of ICT or in social interaction with peers. We argue that an ICT-based artefact attains this role when it becomes *an integrated part* of the interactional forms that are required for constructing knowledge collaboratively (Fjuk & Smørdal, 1998). When an ICT-based artefact attains this role, first it implies that the use of it is conducted automatically due to the actor's internalisation of the properties and conditions of the particular artefact. Second, the use of the artefact must not hamper the focus and object of collaborative knowledge construction.

According to the latter effect, effect of, Salomon proclaims that ICT-mediated collaborative learning covers more than design and use of ICT-based artefacts. He emphasises the role of *mindful engagement*, that is, the processes of active construction controlled by the learners. This effect advocates lasting changes were the students solo-capabilities are improved through intellectual partnership and genuine collaboration. Salomon proclaims that genuine collaboration requires opportunities for maintaining *genuine interdependence*. He characterises genuine interdependence by the following activities:

- The necessity to *share information*, meanings, conceptions and conclusions.
- A *division of labour* where roles of actors complement one another in a joint endeavour and the end product requires this pooling of different roles.
- The need for *joint thinking in explicit terms* that can be examined, changed, and elaborated upon by peers.

Concluding, this implies according to Salomon (1992) that "effects with CSCL are necessary (but not sufficient) condition for the attainment of effects of it".

Discussion: The situated effects of awareness

To provide desired learning effects of ICT-mediated collaborative learning, genuine collaboration and ICT-based artefacts must be considered in terms of an well-orchestrated wholeness (Salomon, 1992). From this position, we suggest that issues on awareness must be consciously sought due to the situated conditions anchored in the socially and artefact mediated aspects of learning. In what follows we discuss the effects of *task* and *workspace awareness* with respect to various conditions that are manifested in artefact-mediated collaborative learning.

Task awareness and interaction about the tasks

A collaborative environment is made up of many tasks carried out over time, and divided according to various situated criteria amongst the learners. This particular features of genuine collaboration concerns issues that Gutwin et al. (1995) call *task awareness*. Task awareness is concerned with how to complete the common task (e.g., What do we know about the task, how much time do we have, what steps must we take to complete the task, etc.). In what follows we discuss the situated effects of task awareness with respect to ICT-mediated collaborative knowledge construction.

We might argue that task awareness is a necessary condition to perform a specific task effectively and to complete an end product in joint endeavour and without breakdowns. However, it is not *sufficient* for providing learning effects of collaboration and social interaction. This is due to the fact that task performance, also, is situated in social interactions and artefact specific conditions:

First, social interaction about tasks is necessary to maintain genuine interdependence. However, the necessary interactional forms constitute possible forces of contingencies and situated actions on both an individual (intra-personal and cognitive) and a collective level (inter-personal). Contingencies on an individual level are for example connected to personal construction of understanding and knowledge, changes of existing knowledge as a result of negotiations, improvement of individual knowledge and interpretations, etc. Contingencies on a collective level are related to for example collaborative negotiation of meaning, inter-personal conflicts and disagreements, division of responsibility, co-ordination of contributions, etc. In the face of contingencies the challenge for the learners is to use the contingencies constructively in developing knowledge and meaning collaboratively and in achieving collective progress, and thus try to reduce the *cognitive distances* amongst themselves (Fjuk & Dirckinck-Holmfeld, 1997).

Second, and in addition to the situated features of collaborative knowledge construction as such, come contingencies associated with the use of ICT-based artefacts (Fjuk & Smørdal, 1998). These types of contingencies may be due to the artefacts' lack of functionality, due to the user's unfamiliarity with them or due to breakdowns in using them. In such situations the artefacts may themselves involve thought and are no longer *integrated tools* in the learners' interactions.

These situated features of ICT-mediated collaborative knowledge construction make collaborative learning *broader* than effective performance of specific tasks and smooth workflow as such. Veen et al (1998) arrive at the conclusion that such efficiency issues are often missions critical in business processes rather than in intentional learning processes. In business, they argue, performance assessment is often based on end products with no explicit reference to process performance. The question of whether the primary production process is efficient or not is critical, since it can mean survival or failure of the enterprise. In collaborative learning, however, the primary goal is to achieve cognitive effects of interactional processes. Efficiency issues are secondary and arise in learning processes only in broad terms (ibid.). Given this situated nature of collaborative learning, the design ideals behind computer systems thus becomes broader than those often focused, that is, to provide mechanisms that increase efficiency of carrying out the tasks and reducing the overhead of working together in distributed contexts (e.g., Schmidt & Bannon, 1992; Divitini & Tuikka, 1996; Gutwin et al, 1996). Rather, we argue that the aim should be to make artefacts that are integrated in social interactions and so that they do not hamper the necessary interdependence between interactions on a collective level (discussions, division of labour, joint thinking, information sharing etc.) and interactions on an individual level (knowledge construction, cognitive re-structuration, performance on tasks, etc.) (Fjuk, 1998). Seen from a computer systems designer's standpoint, however, the relation between individually and collaboratively oriented interactions often conflict, forcing designers to make computer-based mechanisms for one at the expense of the other (Fjuk & Smørdal, 1998; Gutwin & Greenberg, 1998). Design that supports individual activities often hinders collaboration, and vice-versa. For example, this trade-off becomes apparent when trying to support both the individual's needs of integrated and transparent tools and control over the artefacts, and the collaborative arrangement's needs regarding workspace awareness, division of labour, creation of joint understanding, etc. It is incorrect, however, to assume that any ICT solution should mediate all actions found crucial for maintaining these issues. Rather, we argue that a particular ICT-based artefact should constitute one of many operators of activities found critical for maintaining genuine interdependence.

Workspace awareness and individual reflection

Workspace awareness information concerns who is in the shared environment, where they are interacting, what they are doing and sometimes how they carry out the tasks. Gutwin et al (1995) emphasises the learning effects of workspace awareness in the following way:

> "a student requires up-to-minute knowledge about other students' interactions with the shared workspace if they are to learn and work together effectively. This awareness is important in collaborative learning for two reasons. First, it reduces the overhead of working together, allowing learners to interact more naturally and more effectively. Second, it enables learners to engage in the practices that allow collaborative learning to occur." (Ibid. p. 148)

According to the authors, it is especially the awareness of others and their activities that allows learners to initiate meaningful interaction. This understanding of collaboration is, arguably, anchored in face-to-face situations where workspace awareness is considered optimal because of the *closeness* between the actors. The aim of systems design is thus to make mechanisms that provide corresponding opportunities, in spite of the physical distances amongst the actors. In what follows we discuss the effects of this type of awareness with respect to collaborative learning.

Although division of labour and joint thinking are collaboratively oriented activities, the activities are often conducted through interactions of *individual* actors, directed towards thought and reflection (on an intra-personal level) or co-learners (on an inter-personal level). Collaborative actors frequently move back and forth between individual tasks performed in relative isolation and shared work undertaken with co-actors. According to the theoretical heritage, these interactional forms provide effects first when they are genuine interdependent, that is, when they are mutually constructive. For example, joint thinking in explicit terms - so that they can be examined, changed, and elaborated upon by peers - requires individual reflection and thought. Moreover, thought, reflection and individual understanding must be co-ordinated with, and have meaning for joint understanding and division of labour. This line of consideration does not necessarily require an up-to-minute information of who has done what and where. The effects of this awareness information become optimal only when the learners are working on the *same* physical object. We argue that opposite conditions than what workspace awareness entails, namely some *distance to peers*, are also required for individual reflection and thus, for maintaining genuine interdependence. When something becomes conscious to, or acknowledged by the individual learner, it happens because she/he is able to reflect on the matter (Sorensen, 1999). Reflection, Sorensen (1999) argues, requires distance to peers. The virtual and distributed environment distinguishes from physical environments exactly because it adds a new reflective dimension to interactions in collaborative learning (Ibid.), since they allow the actors to "get off-stage" for some time.

Thus, the desired effects of workspace awareness are situated with respect to what aspects that are considered critical at what time of the collaborative processes. We argue that mindful engagement and genuine interdependence require opportunities to *move* between a closeness to peers through some extents of workspace awareness, and a distance to peers in order to articulate thoughts through reflection. This means that designs aimed at providing solutions for this situatedness must, as suggested in the previous sub-section, try to find a balance between individually and collectively oriented interactions and so that the ICT-based artefacts do not hamper the necessary interdependence of the whole collaborative activity.

An example: Corpus Callosum

In what follows we illustrate how some of the issues discussed have been implemented into designs of one particular interactive *3D* application — *Corpus Callosum*.

Loeffler & Andersen (1994) defines interactive 3D as:

> "a three dimensional, computer-based, simulated room, that is synchronous according to the users movements and perspectives" (Ibid. p. 12).

This implies that interactive 3D imposes dynamic and situated environments that are created by the actors through their actions. In the case presented in this paper, the 3D application includes an additional dimension: Physical distribution of actors.

Corpus Callosum: Pedagogical and technological designs

The target group of the 3D application is 14-years old learners. To stimulate their engagement and social interaction we invited a couple of them to participate in the first stages of concept-development. The problem area was manifested in ‘an ecological catastrophe at a synthetic planet’ according to the young learners’ desire. This planet was later called ‘Corpus Callosum’. Parts of the story go like this:

> There have been a lot of tremors at the planet and it has resulted in a number of ecological problems. One of them is the heat that threats some areas of the planet. The iron three, Nucleus, is the central point at the planet and it is particularly exposed. Nucleus can whenever crack and fall apart. This might bring catastrophic consequences for Corpus Callosum because Nucleus takes care of two central functions. The first one, is internal oriented when Nucleus is the major source of oxygen at the planet. The second one, is external oriented when Nucleus might be the only possibility to avoid that the planet should be forgotten by inhabitants of other planets because this three is able to send signals out to space. To avoid a complete catastrophe, Nucleus must be supplied with spinalfluid. This is operationalised by re-building the Aqueduct. During the planet tremor was the Aqueduct that supplied Nucleus with spinalfluid from the Hippomania-sea to Nucleus' roots destroyed into small pieces. Each of the parts was spread far away and landed in different areas of the Hippomania-sea.

Various metaphors are used in the graphical design of Corpus Callosum: Latin vocabulary associated with the brain as well as aspects from Nordic mythology are used. This implicates that in Corpus Callosum the names of the territories are selected from regions of the brain like Thalamus, Homunculus etc. According to the creation of earth in Nordic mythology, these territories are placed in various circles and were each surrounds the previous one. Figure 2 gives an overview of the planet.

The relationship between *artefacts* and *actions* is operationalised with help of two terms: Avatar and object. An *avatar* represents an actor in the learning environment. Some avatars are designed as humanoids;

others are without any resemblance to humans. In Corpus Callossum avatars represent the learners and the tutor.

According to the theoretical basis, an artefact represents certain conditions that determine what can be carried out, in what form and for what purpose. As such, it shapes the way people act and influences the nature of human interactions. The *objects* constitute the major artefacts of the collaborative 3D environment. Each part of the destroyed Aqueduct or the whole

Aqueduct when it is re-built are examples of such objects. Moreover, there are particularly three relationships that operationalise Salomon's (1992) two kinds of effects. These are actor-object, object-object and, actor-actor. In line with the theoretical heritage, the relationships cannot be considered *separately* but *mutually*.

4.1.1 Actor-object

The effects with the artefacts (that is, the changes or results afforded during the use of available objects) are particular present in the actor-object and the object-object relationship. The actor-object relationship represents first and foremost a learner's actions mediated by an object. This operationalisation is conducted by manipulating the object directly by clicking, lifting, moving, etc. For example, in Corpus Callosum different parts of the Aqueduct are spread around in the different areas of the planet (Thalamus, Homunculus etc). According to the manipulation of objects this implies that the learners can pick up a part of the Aqueduct from one area, bring it with them and place it together with other similar elements until the whole Aqueduct is built. Figure 1 illustrates a built aqueduct and its connection to the iron three Nucleus and the Hippomania sea.

The actor-object relationship clearly supports awareness information of how a task is complete. This is because the learners internalise the *same images* and this ability reduces the need to meta-communicate all interactions. But, in line with our arguments concerning the situatedness of ICT-mediated genuine collaboration, the aim is not necessarily to achieve knowledge regarding who is doing *what, how, where* and *when* in all parts of the collaboration. Rather, the aim is also to create opportunities for individual reflection. As suggested, the designs' ideals thus become to create opportunities for the learner to *move* between a closeness to peers through some extents of workspace awareness, and a distance to peers in order to articulate thoughts through reflection. These design ideals are manifested in Corpus Callosum in the following way: A learner is aware of certain actor-object relationships that are operationalised within her/his field of cognisance. Workspace awareness is optimal when two or more learners are located in the same area (such as Thalamus) for example when jointly building the Aqueduct. In contrast, the effects of workspace awareness are limited when the learners are situated in separate areas. In Corpus Callosum this is manifested in situations where the individual learners, on basis of their common decisions and division of labour, are located in various areas aimed at finding new objects and performing actions on them, or at individually reflecting upon the problem areas and tasks.

3.1.2 Object-object

The object-object relationship concerns how manipulation on one object, influences the *situated conditions* of another object. Nucleus is an example of an object that is socially and contextually situated. Nucleus shifts colour according to the learners' actions on it and on other objects linked to it (such as the Aqueduct). Nucleus signals whether the actions are appropriately operationalised vis-à-vis the problem area (ecological disaster) and corresponding tasks. This object-object relationship has a twofold effect on collaborative learning and awareness information. On the one hand, it explicitly visualises the consequences of the individual's actions on an object and constitutes an essential means for further actions related to divisions of tasks and discussions about the tasks. On the other hand, it mediates the learner's information awareness on how her/his action constitutes a part of a *greater wholeness*. This is an essential factor in how well an environment creates opportunities for collaborative learning, rather than workspace awareness and task performance *per se*.

3.1.3 Actor-actor

According to our arguments, efficient task performance is not sufficient for providing effects of socially and artefact-mediated learning. Rather, the effects of ICT-mediated genuine collaboration become optimal when the distributed environment creates opportunities for discussions about the tasks (C.f. Dillenbourg (1996)). The actor-actor relationship focuses particularly on this argument. Oral dialogues between the actors mediate this interaction, but also by the two other relationships (actor-object, object-object). One way to provide effects of this relationship is to organise for good interactional conditions so as they stimulate the learner's mindful engagement, personal responsibility and discussions. This is first and foremost connected to the problem area (the ecological disaster) and corresponding tasks. Then, it is associated with the tutor's secondary role and is more moderator-oriented in their relation to the collaborating peers.

Good conditions for mindful engagement are connected to the learners' opportunity to take part in the problem definition and how this in turn motivates and engages the learners in inter-personal interaction. In doing so, the learners have a conscious ownership of their own learning processes and are implicitly invited to involvement and motivation (Fjuk & Dirckinck-Holmfeld, 1997). In the pedagogical designs connected to Corpus Callosum, the learners defined the particular problem (in accordance with the given problem area of ecological disaster) they were going to collaboratively reflect upon, discuss and make shared representation of.

Concerning the tutor's role in distributed environments, some aspects of scaffolding must be maintained. In many cases scaffolding refers to processes of developing forms of instruction, which maximise internalisation within collaborative environment (McMahon & O'Neill, 1992). The learner internalises the scaffolding and advises given by more capable peer (often the tutor). Scaffolding can thus be considered as the opposite of the learners' control and ownership of problems, through its focus on pre-defined problems and tasks. Task awareness may provide explicit scaffolds to help stay on the task. Moreover, the tutor's role must also be related to the social interactions as such, that is, to reduce stagnation on the one hand and, to stimulate discussion and engagement on the other. In Corpus Callosum, this was maintained and visualised through an *own avatar*. The tutor's avatar, Lobos, is a kind of old fashion robot that is stuck in Nucleus. This avatar is not able to move and it cannot interact with the objects in the planet. The tutor has thus a passive but central position since her/his avatar has been lifted up from the ground in such a way that she/he gets an overview of the learners' activities. In this way she/he can more easily counsel the learners, but only when they ask her/him to do so.

5. Conclusion and further work

In this paper, we have discussed the problem area of addressing the effects of task and workspace awareness with respect to learning. Based on theories (Vygotsky (1978); Salomon (1992)) on how social interactions and artefacts (such as for example various forms of ICT) pull cognitive changes and human development, we have argued that the effects of task awareness and workspace awareness are *situated* with respect to the various interactional forms manifested in collaborative learning situations. That is, these types of awareness are not sufficient enough for providing certain cognitive and collective effects of artefact-mediated collaboration. Thus, the aim behind systems design becomes broader than making artefacts that support efficient work flow and task performance. Rather, we argue, that systems design should be aimed at making and organising artefacts that become integrated parts of the whole collaborative activity and in such a way that they do not hamper the necessary interdependence between interactional forms on an individual and collective level. We have illustrated some issues of this argument with examples gathered from designs of a specific interactive 3D application. This becomes particularly evident through three relationships that are situated in the properties and conditions of interactive 3D applications. These are actor-object, object-object and actor-actor relations. The objects represents artefacts that, through their predefined conditions and relations, shape the way the learners act and collaborate: The actor-object and object-object relationships concern the changes or results afforded during the *use* of the artefacts. The relationships represent a learner's interactions mediated by an object (in the 3D environment) and how this mediation affects the collaboration and individual knowledge construction. The actor-actor relationship concerns pedagogical and interactional conditions for maintaining mindful engagement and discussions, and is based on the learners' opportunity to take part in the problem definition and how this in turn motivates and engages them. This interaction is mediated by *oral dialogues* between the actors as well as by the two other relationships (actor-object, object-object).

The theoretical foundation has provided rich insights into a design process of taking the effects of ICT-mediated collaborative learning seriously into consideration. The theory has served as adequate means related to our intentions as technological and pedagogical designers; to support the learners' activities of creating a common learning environment in such a way that interactive 3D becomes an integrated part of the learners' collaborative knowledge construction. However, the real effects of collaboration and interactive 3D can first be identified through the learners' talk on use-experiences. Thus, our further research in this area will move into two directions: First, we will conduct qualitative evaluations of the learners' and the tutor's experiences of using the application. This will explore aspects that must be included in pedagogical and technological re-designs. Second, we want to look more closely at the links between various types of awareness with respect to collaborative learning processes where negotiation of meaning and critical reflection constitute two major pedagogical principles. We believe that this is necessary to create new learning situations that provide effects with respect to learning and knowledge construction.

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