Abstract: In the present paper we address the sociocultural foundations of knowledge-creating inquiry by examining the role of epistemic mediation in technology-mediated learning. We argue that technology-mediated collaborative learning provides participants with amplified semiotic resources based on temporally integrated (bringing crystallized earlier cognitions to present) and spatially merged virtual and social spaces of activity, constituting a specific chronotope. Epistemic mediation, based on writing and visualization, involves the creation of epistemic artifacts that crystallize cognitive processes, re-mediate subsequent activity, and constitute an evolving network that triggers expanded inquiry. Technology-mediated learning is a multi-modal process involving different processes such as discussing, reading, writing, sketching, etc., which cognitive value is dependent on sustained epistemic mediation. The cultivation of the chronotope of technology-mediated learning requires expansive learning efforts that transform the entire activity system. Investigation of the collaborative emergence of such chronotopes appears to be a promising line of advancing inquiry in the field of CSCL.

Introduction

When the Nobel-winning American physicist Richard Feynman gave a manuscript full of text and diagrams to Charles Weiner who was investigating the history of his thought, the latter asked if this was “a record of the day-to-day working”. “I actually did the work on the paper” Feynman responded. Slightly confused Weiner specified: “Well, the work was done in your head, but the record of it is still here.” “No, it’s not a record, not really. It’s working. You have to work on paper, and this is the paper. Okay?” (Gleick, 1992, p. 409, quoted by Donald, 2001, p. 301). From the perspective of the foundations of technology-mediated learning, it is essential to acknowledge that human beings do not have cognitive capacities to entertain truly complex ideas within their individual minds; in order to pursue “longer trains of thought” (Darwin, quoted by Gruber 1980) they have to “work on paper”. Experts’ complex reasoning and memory capabilities emerge only through sustained pursuit of externally embodied cognitions. This process involves utilizing various External Memory Fields (EXMF, Donald, 1991), such as paper and pencil, for extensive elaboration of ideas so as cope with the cognitive processing load involved in complex problem solving and pursuit of novelty. The human cognitive evolution involves cultural invention of epistemic technologies, such as writing and visualization, which radically collectivize cognitive processes traditionally taking place within the human mind. When designing technology-mediated learning environments, investigators are, simultaneously, deliberately creating new types of EXMFs for personal and collective augmentation of cognition and, thereby, providing material agency (Pickering, 1995) for pursuing more complex inquiries that would otherwise be possible. The present tremendous expansion of the ICTs is a part of the same collective transformation that took place at the advent of modern civilization and changed the architecture of human cognition as radically as earlier leaps in biological evolution (Donald, 2001). A central aspect of such transformations was epistemic mediation, i.e., a process and practices of deliberately re-mediating personal and collective activity by creating shareable epistemic artifacts, such as texts. Creating such epistemic artifacts enable participants to externalize, objectify, and materialize their epistemical processes to shareable knowledge-laden objects, a growing network of which remediate subsequent inquiry efforts. Productive utilization of epistemic mediation in learning and inquiry presupposes, however, sustained efforts to use associated technologies in practice and cultivating required personal skills and practices (Hakkarainen et al., 2009). Rather than being a simple part of observable physical space, EXMF is a part of a dynamic semiotic field that intersect boundaries of mental (activated internal epistemic resources), virtual (technology-mediated instruments), and social (on-going interaction and collaboration) spaces of activity (Nonaka & Konno, 1998), which can be considered elements of the chronotope of technology-mediated learning (Ligorio & Ritella, 2010).

Chronotope is Bakhtin’s (1980) concept originally devised for understanding how literate genres of novels define their own reality; specific ways of interconnecting spatial and temporal relations (Tuomi, 2002). Bakhtin argued that each mode of thought has its own genre (Bazerman, 1988), i.e., socially and culturally recognizable and repeated, production of typified epistemic artifacts in human collectives. Such genres represent historically evolved social practices; the associated chronotope involves certain ways of perceiving the world. For our purposes, we define the chronotope in technologically-mediated collaborative environments by noting that it is an approach that guides one to examine both temporal and spatial implications of technology-mediation. In fact, the temporal structure of activity is transformed in terms of changing participants’ intangible ideas to shared epistemic artifacts and, thereby, bringing results of past inquiries to present. Moreover, the entire flow of activity, in terms of temporally organized sequence of actions undertaken by subjects, is impacted by the use of different types of EXMF. The spatial transformation, instead, involves 1) sharing inquiries regardless of location and making remote information sources immediately accessible and 2) interacting with qualitatively different EXMF that provide subjects with semiotic spaces organized in multiple ways. Suffice it to think of the difference between the ways in which books are organized in a library from the way in which they are organized in Google books. Technology-mediated practices of working with knowledge, then, both transform the flow of activity and bring qualitative changes when dynamic ICT-based tools are integrated as instruments of activity. Following Bakhtin, we consider these spatial and temporal processes to be fused: the creation of epistemic artifacts is a temporal process but its results involve items in space. Similarly the organization of the space impacts the temporal organization of activity. The
concept of chronotope guides investigators to trace how time and space of technology-mediated learning impact each other, [and in] consolidating technology-mediated collaborative learning practices, they may become partially interwoven at the emergence of a novel chronotope. Yet chronotope is meant to invoke a whole, so that ‘reciprocal impact’ is at best a first approximation in the understanding of whole synchronous process with its various aspects.

Chronotope is closely associated with concepts as activity system (Engeström, 1987), affinity space (Gee, 2005); ba (Nonaka & Konno, 1998); epistemic practice (Knorr-Cetina, 2001; Hakkarainen, 2009), and social practice (Schatzki, 2000), which are aimed at understanding and explaining mediated, socially distributed aspects of learning and inquiry, which develop through technology use. An examination of the chronotope of technology-mediated learning is important because ICTs break many traditional spatial and temporal boundaries of human activity. Indeed, technology-augmented educational settings are to be considered what Foucault (1967) called a complex “heterotopia”, i.e. a place in which multiple types of physical and symbolic space coexist and alternate. Rather than taking place within the human mind, then, thinking and learning are seen as processes stretched over and distributed across semiotic spaces that ICTs and associated EXMFs provide so that the external environment is an essential aspect of cognitive processes (Donald, 2001; Clark, 2008; Vygotsky, 1978). Our study is based on an assumption that by investigating carefully spatial and temporal configuration of technology-mediated activity and associated personal and collective competencies, it is possible to achieve deeper understanding regarding the implementation of new technologies in educational and knowledge-intensive activity. The present paper examines, by building on the original inspiration of Ligorio & Ritella (2010), the emergence of chronotope of technology-mediated learning. Toward that end, we will address 1) writing-related social practices in epistemic mediation; 2) the nature of epistemic artifact that mediate CSCL; 3) relations between chronotope and shared knowledge practices, and 4) collaborative emergence of innovative inquiry practices.

Writing as a principal vehicle of epistemic mediation

Research on social interaction taking place in CSCL assists in understanding situational and dialogical processes of meaning making, knowledge construction, and argumentation. A starting point for the present article, however, is a realization that, in epistemic terms, talking is silver and writing is gold; serious inquiry cannot rely on mere oral interaction but needs to capitalize on literate practices involved in systematic production of epistemic artifacts that are textual or graphic in nature. The chronotope, i.e., dynamic spatiotemporal configuration, of the literate mode of thought characteristic of an advanced knowledge society is mediated by systematic creation of epistemic artifacts by writing and visualization that enable radical collectivization of human cognition. The human cognitive architecture was transformed as profoundly as in the context of significant leaps of biological evolution, when the new EXMFs emerged that allowed radical externalization and collectivization of cognition (Donald, 1991; 2001). Writing technology enabled human beings to materialize their cognitive processes of shareable epistemic artifacts: Intellectual capacities are substantially expanded when a hard copy of cognitive processing results can be made and serve as base for subsequently personal and collective inquiries. Yet, it represented a cultural innovation that the hardware of the modern human developed outside rather than inside of the mind. Writing and visualization allowed human beings to establish a theoretic culture based on gradually accumulating External Symbolic Storage Systems (ESSSs, Donald, 1991). Hence, human beings are maximal cognitive over-achievers because they use writing and other cognitive extensions to piggy-back complex cognitions that could not be implemented without external aids (Clark, 2008; Donald, 2001). The collectivizing evolution of human activity has not ended but continues in the area of developing ICTs that allow delegating cognitive processes to technological systems, creating technologies for collaborative merging and fusing intellectual efforts, and complementing personal epistemic resources with global networks that are accessible as immediately as personal memories.

Writing, then, has to be considered the principal vehicle of epistemic mediation. Pioneering research on epistemic mediation related to CSCL has been carried out by Scardamalia and Bereiter (2006). Investigations focused on studying psychology of written composition (Bereiter & Scardamalia, 1987), revealed that while novices reported what they knew in the order and form issues became to their mind (knowledge- telling strategy), expert efforts of tailoring their knowledge to the audience, by moving between content and rhetorical space, often generate new knowledge and insights (knowledge- transformation strategy). Efforts of teaching novices the experts’ strategy needed procedural facilitation, i.e., representing materially embodied critical questions (pieces of paper) that experts spontaneously pose at the EXMF of the participants. When relying on such distributed intellectual resources novices improved the quality of their writing. Later on such cognitive scaffolding played a crucial role in the design of knowledge-building technologies focused on assisting students engagement in complex and challenging inquiries in which material practices of writing played critical role. Although writing may be seen in terms of developing participants’ ideas, it appears essential to acknowledge the material-symbolic nature of the associated chronotope; writing takes place in a spacetime and involves constants externalization and materialization of thoughts to external artifacts; the material agency (Pickering, 1995) provided by CSCL technology makes even elementary-school students capable of knowledge advancement.

Writing is, further, not just recording of thought but constitutes its own system that has significant social, intellectual, and cultural consequences (Brockmeier & Olson, 2009). The corresponding chronotope relies on material-symbolic practices that enable creation of new kinds of epistemic objects and systems, such as questions and theories, with which we can be in interaction. In order to cultivate capacities of pursuing challenging inquiries, students have to be intellectually socialized to augment their cognitive resources by deliberately working at EXMFs and appropriate genres of academic writing. The textual practices prevailing at school guide students, however, to use writing for reporting what their textbooks say about issues being studied rather than use writing as a tool of extending their thinking and deliberately generating new ideas and working theories. Learning to use writing as a tool of thinking is extremely hard; it is an extended struggle to acquire embodied and to a large extent tacit capabilities rather than direct assimilation of well-specified skills (Russell, 1997). Epistemic socialization to literate practices allows students to become authoritative agents of knowledge-advancement efforts. While producing their texts, the students are, simultaneously, also authoring themselves and cultivating their own academic voices (Holland et al., 1998). By guiding and supporting students writing and local publication, the teacher and collaborative learning community may assist in formation of
identity as a prospective builder and authoritative creator of knowledge. The participants are likely to need specific guidance regarding principles, practices, and ethical norms regarding writing to open collaborative spaces.

**Shareable epistemic artifacts mediating inquiry**

Epistemic artifacts play an important role in “knowledge-creation learning” that the first author and his colleagues have been developing (Paavola et al., 2004). We are talking about object-centered approach to CSCL because the nature of the objects worked on significantly determines, the nature of inquiry and are centers around which corresponding chronotope is organized. The concept of “object” has philosophic roots in Hegel’s and Marx’s as well as Peirce’s and Popper’s studies, and psychological roots in knowledge building (Bereiter, 2002) and activity theory (Engeström, 1987). We understand learning as a form of trialogical activity focused on collaboratively advancing a shared object of inquiry, whether it is a research problem, theory, product, practice (to be transformed), or project. Trialogical inquiry does not emphasize individuals or communities as such but the ways participants collaboratively develop mediating artifacts in long-term processes.

Scardamalia and Bereiter’s (2006) knowledge building framework aims at making a Copernican revolution in education in terms of putting student-generated ideas to the center of education. Their design experiments guide students to deliberately build local collective knowledge by creating, sharing, and advancing epistemic artifacts (externalized ideas) with assistance of collaborative Knowledge-Forum technology. An innovative movement was to examining learning communities as ones for building and creating their own local body of cultural knowledge. The way students work with ideas in knowledge-building classrooms is different from ordinary oral discourse taking place in conventional classrooms; participants’ intangible insights entered to learning environments databases are transformed to digital form and therefore, also, materially embodied ideas that exist outside of the participants’ minds. Such entities are conceptual artifacts (Bereiter, 2002) having both ideal and thing-like characteristics. The specific nature of material embodiment and external representation of ideas affects significantly how the artifacts can be used and utilized in inquiry; this aspect of objects is disregarded by Popper’s (1972) analysis privileging conceptual content of knowledge objects.

From the perspective of cultural-historical activity theory (Engeström, 1987), epistemic mediation is one aspect of human sign- and tool-mediated activity. Ideas and conceptualizations generated are seen as psychological tools which assist participants in guiding their materially embodied activities (Vygotsky, 1978); the development of ICTs appears to bring radical collectivization of such tools about. Epistemic processes are, however, inherently integrated with material object-oriented activities and should not be seen as a separated sphere of activity. Human designed materially embodied artifacts literally bear knowledge (Baird, 2004); such thing knowledge may assist in modeling phenomena (representational function), explaining and prediction (functioning in a way analogous to theories), and performing a function (working knowledge). The design of an artifact embodies in a crystallized form a whole expert network’s knowledge that can be taken as a black box in subsequent use of the artifact (Tuomi, 2002). There is evidence that hybrid practices of engaging students in parallel efforts of conceptually-driven knowledge-building inquiry and designing materially embodied artifacts facilitate student learning and motivation (Kangas et al., 2007).

From an activity-theoretical perspective it is essential to elicit spatial and temporary expansion of object of activity (Engeström et al., 2004) in terms of students not only focusing on assimilating textbook knowledge and doing associated narrow and impoverished learning task but addressing truly complex, challenging, and varying problems; independent solving of which prepares them for encounters with unforeseen problems of the future (Marton & Trigwell, 2000). Toward that end, knowledge-creating inquiry engages students deliberately in working with openly defined “epistemic objects” prevailing at the edge of their epistemic horizon and incorporating what they do not yet know (Rheinberger, 1997). Such open-ended objects constantly generate novel questions and become more and more complex when pursued. Hence, epistemic mediation appears to be a dynamic process that involves constant re-interpretation and iterative articulation of epistemic artifacts (Bereiter, 2002; Skagerstad, 1993; Paavola et al., 2004). Collaborative pursuit of epistemic artifacts appears to piggy-back advancement of young students’ inquiry within knowledge building classrooms by capitalizing on double stimulation (Vygotsky, 1978); accordingly, inquiry challenges (first stimulus) are pursued by engaging students themselves in deliberate creation of external, shareable epistemic artifacts (second stimulus) in interaction with which subsequent inquiry efforts take place. It is essential that the artifacts be materially embodied so as to transform the expanded problem space (EXMF) and become a sign on the basis of which a subsequent leap of inquiry can be accomplished; without external embodiment that double stimulation would not work and assist in bringing novelty about. A part of double stimulation is to have epistemic objects involving “pointers” (hints, implicit directions) regarding what is missing from the picture, and thereby, intuitively suggesting which way to look and how to focus further inquiries (Knoor Cetina, 1999). In the course of activity, epistemic artifacts may become instruments for subsequent inquiry efforts, making them a part of the invisible background of activities – intuitively guiding and constraining further inquiries (Engeström, 1987). Learners may appropriate knowledge-building practices to the extent that pursuit of epistemic mediation relevant for knowledge-creation becomes their second nature, i.e., an integral aspect of their activity system. Moreover, creation of epistemic artifacts is not cognitively neutral but contributes to expansive stimulation, i.e., a long series of double stimulation processes, which massively reformat and restructure the participants’ minds (compare re-presentational re-description, Karmiloff-Smith, 1992) across sustained efforts.

**Knowledge practices: a chronotope of technology-mediated learning**

From our perspective, research on CSCL has serious lacks if it merely focuses on either providing an account of here-and-now practical activity and associated social interaction or analyzing the content of textual artifacts (and ideas involved) generated. In order to obtain comprehensive understanding of the chronotope of technology-mediated learning, such learning has to be studied as multimodal and “laminated” (i.e., spatiotemporally layered) activity (Prior, 1998) in which social practices related to epistemic mediation play a crucial role. Following a similar thread from the perspective of classroom pedagogy, Brown and Renshaw (2006, p. 249) have shown how pupils participation in classroom activities is linked to the way in which they discursively shape “the space-time context of the classroom” and to the way they “ground” their thoughts. In our perspective, we designate by chronotope the emergent pattern of spatial and temporal structure and arrangement of activity within a computer-supported community. Being
at the intersection between space and time, it has been characterized elsewhere by the use of the musical metaphor for the analysis of the tempo of the flow of activity. So, three chronotopes have been identified, related to different rhythms emergent in collaborative interaction (Ligorio & Ritella, 2010): 1) adagio, characterized by a slow flow of the activity 2) andante, characterized by an acceleration in the flow of the activity and 3) allegretto, in which the configuration of participation allow a fluid and dynamic course of actions. Some specific features such as the “the depth and the size of the space of interaction” and “how participants move around the computer and within the digital space” play an important role in the emergence of chronotope (Ligorio & Ritella, 2010).

The chronotope of technology-mediated learning appears to be embedded in shared knowledge practices cultivated by knowledge communities (Hakkarainen, 2009; Hakkarainen et al., 2009). By knowledge practices, in turn, we refer to personal and social practices related to working with knowledge; epistemic mediation plays a central role is such practices. Social practices are assemblages of human activity that involve goal-directed sequences of actions using certain technology and relying on a socio-historically developed system of knowledge (Schatzki, 2002; Scribner & Cole, 1981). The term “knowledge” is used in the broadest sense, to include procedural and implicit as well as explicit and objectified knowledge. Advancement of inquiry requires participants to engage in systematic creative reinvention of their inquiry practices so as to elicit knowledge processes characterized by novelty and innovation (Knorr Cetina, 1999: 2001). Current theories of social practices relevant for professional expertise highlight both the inseparability of knowing and doing and the creative and improvisational aspect of practice. Knowledge-creating communities rely on “weakly determined, unstable, explorative, and problem-laden practices that are once in a while innovative” (Knorr Cetina, 2001). Knowledge practices, while sometimes just supporting routine learning (transmission), at their creative edge diverge from routine social practices in that they take place in specific, purposefully dynamic, and fluid settings designed for the furtherance of innovation and knowledge. Rather than relying only on mere mundane habits or repeated routines (that may also be needed), such practices are aimed at solving problems emerging at the edge of creative inquiry. The driving force in the development of such practices is a constant dance between resistance and accommodation (Pickering, 1995); the pursuit of emerging networks of projects in a changing world through reliance on epistemic competencies that were created spontaneously leads to frequent disturbances, tensions, breakdowns, and contradictions. Solving these requires the reciprocal tuning of material and human agency (Pickering, 1995). It may be argued that in the case of communities that follow such practices, innovation and pursuit of novelty are themselves transformed to shared social practices through the cultivation of corresponding personal and collective competencies and patterns of shared activity. Whenever such innovative practices are encountered, we are dealing with innovative knowledge communities and their networks (Hakkarainen et al., 2004).

Moreover, as we argued previously, the creation of epistemic artifacts impacts the entire practice of knowledge creation and the underlying cognitive processes by altering the space-time structure of knowledge creation. Knowledge-creating learning is mediated by deliberate construction of epistemic artifacts that crystallize the participants’ intellectual processes, and the evolving network of which guides subsequent inquiry efforts of the participants. The temporal structure of activity is transformed at a very fundamental level in this process. In fact, technology-mediated collaborative learning impact the context of learning providing participants amplified semiotic resources based on integrated and partially merged physical, virtual, social and mental spaces of activity. Digital epistemic artifacts even transform and enrich the heterotopia of mediated learning, while ICTs permit users to create easily shareable and workable epistemic artifacts. Consequently, CSCL is a temporally layered phenomenon; allowing externalization, objectification, materialization of intangible ideas so that those can be used as a starting point in the subsequent inquiry. Pursuit of such artifacts entail also cultivation of corresponding social practices that channel the participants activities in a way that elicit advancement of inquiry; hence ICT mediated knowledge practices appear to define certain chronotopes that allow deliberate collaborative pursuit of knowledge advancement. Expansive stimulation is an integrated aspect of such process in that epistemic artifacts provoke a long series of double-stimulation experiences that guide further direction of inquiry (Hakkarainen et al., 2009). The following principal features appear to characterize the chronotope of knowledge practices for technology-mediated learning:

• The chronotope is marked by changes in the tempo of the ongoing activity and occasional spatio-temporal intensification of collaborative activity, and it permits us to explain variation in the pace as well in the emerging organization of the collaborative process (Ligorio & Ritella, 2010);
• The chronotope of knowledge-creating learning is mediate by collaborative technology, such as Knowledge Forum, that amplifies and expands possibility of inquiry of a physically present learning community, generating “blended learning communities” (Ligorio, 2009). While any type of virtual learning may have its own chronotope they are not the focus of the present investigation.
• The architecture of sophisticated technology-mediated learning is that of a textual culture; consequently epistemic mediation plays a crucial role in the corresponding chronotope. Epistemic mediation is the principal mechanism of temporal integration between past, present, and future. Thanks to text durability and workability enhanced by the ICTs, past inquiries crystallized in epistemic artifacts transform current distributed problem space and provide anticipatory guidance for directing future inquiry.
• Simultaneously, the chronotope of technology-mediated learning is heterogeneous and multi-modal in nature. If follows that epistemic mediation should not be examined only as an actual production of texts because it involves actions hybridizing and inter-mixing modalities and medias. Typically, discursive activities also involve successive periods of reading and writing, searching information and exchanging emails, thinking and talking, drafting and reviewing, intensive writing and taking a break, and solo and collaborative working. Writing taking place in CSCL is laminated/layered in respect of taking place in the context of heterogeneous networks activities from field trips to classroom experiment, library visits, internet searches and so on.
• The chronotope of technology-mediated learning is also laminated in respect of being locally improvised in conjunction with being mediated by socio-historically developed genre, technology-based instruments, and educational practices (Prior, 1998). So, while the chronotope may be examined in terms of situational and improvised here-and-now activities, it is essential also to address not only micro- but also meso- and macro-level fluctuations and transformations of activity. As explained below, a chronotope of mature inquiry is a developmental achievement that emerges collaboratively through sustained collective efforts.
Collaborative emergence of knowledge-creating chronotope

Innovative practices of working with knowledge and the associated chronotope are developmental achievements related to expansive transformation of practices of using technologies. Consequently, we argue that technology enhances learning only through transformed social practices (Hakkarainen, 2009). All successful cultures of CSCL appear to be simultaneously also expansive-learning communities (Engeström, 1987) focused on problematizing current practices, envisioning changes, and gradually, step-by-step, consolidating novel inquiry practices. Only when CSCL technologies are embedded in knowledge practices that guide the participants to systematically pursue inquiry and create, share, and further develop epistemic artifacts, is technology-mediated learning is likely to produce worthwhile results. The participants have to learn to seamlessly integrate their personal and collective activities with collaborative technology, including systematic pursuit of inquiry, externalizing and materializing inquiry processes to shared artifacts, and productively capitalizing on artifacts created by the fellow inquirers and so on. Accordingly, the emergence of the new chronotope of ICTs mediated knowledge creation implies both the transformation of the physical and symbolic space and of the practices that occur within that space. That new pattern of space arrangement and new practices, generates also a new time perspective associated with them and impacts the tempo of the activity, making the new chronotope emerge.

Many CSCL experiments, some of them carried out by the present investigators, however, focus on one-shot experiments in which a group of student has to learn both a novel pedagogy (progressive knowledge-building inquiry) as well as re-mediate their activities with a collaborative technology. In many case, the temporal scope of the experiment is such that the participants do not go through the expansive learning required for transforming their knowledge practices deeply enough to create a chronotope of knowledge-creating activity. When CSCL technologies are taken to a new classroom, the chronotope of traditional school learning is likely to prevail with associated personal roles and responsibilities, individual learning tasks and assessments, and genre-related patterns of asking fact-seeking questions and using information sources reproductively. The technology is initially likely to represent a mere additional layer of activity, and its usage easily involves excessive copying of knowledge. In order to elicit expansive learning, it is essential to engage participants in practical activities which integrate the use of ICTs; it is a developmental process of making technological artifacts into instruments of the participants’ activity (instrument genesis, Beguin & Rabardel, 2000). On the one hand this impacts the perception and the arrangement of the physical and symbolical space of knowledge practices. On the other hand, it requires practice to adapt to a new space and the new time perspective associated with it. Initially fragile and error-prone activities become more stable after corresponding operations and actions become consolidated and the participants’ capacity to troubleshoot ruptures and breakdowns improves. While the participants are likely to be initially dependent on guidance provided by visible ICT mediated objects, structures, and processes, it is gradually replaced by anticipatory response to the likely progress of the situation.

The development of chronotope of innovative knowledge-creating inquiry is, then, a collaboratively emergent process (Sawyer, 2005) seldom analyzed by investigators who either pursue one-shot experiments or describe locally created mature inquiry cultures. Collaborative emergence is a methodological perspective for studying the dynamic and fluid, recursive and iterative aspects of inquiry and evolving knowledge practices (Sawyer, 2005). Detailed multi-level data on transformative personal and collective activities are needed so as to be able to account for such dynamic emergent processes. In fact, directed evolution of practices is elicited by selectively consolidating ephemeral (temporally varying patterns of participating and interacting in relation to evolving themes and contexts) as well as stable (group cultures, discursive routines, shared practices, collective memory) emergent possibilities of CSCL. Through sustained collaborative improvisation, ideas, artifacts, methods and practices that do not belong to any one of the individual participants emerge situationally and interactionally from self-organized collaborative processes (Fleck, 1979). Tensions, ruptures, breakdowns and discontinuities of activity may be seen as important signs of the collaborative emergence of novelty. Emerging novel elements or aspects of activity break the smooth flow of activity down and push the participants personally or collectively to explore novel possibilities, transform prevailing instruments and practices, and utilize resulting changes in the situation in order to find opportunities for taking inquiry forward. The collaborative emergence of a new chronotope may be studied at micro-, meso-, and macro-levels. Micro-level involves analyzing real-time improvisational activity; meso-level addresses collaborative emergence in pursuing an inquiry project as a whole; and macro-level involves expansive learning across (generations of) projects. There is a complex interaction among teachers’ guiding efforts, students’ goal-directed activities, the evolving network of epistemic artifacts, and the contextual pursuit of inquiry. Through it emerges collaboratively ephemeral possibilities that need to be recognized, utilized, extended and stabilized so as to advance inquiry.

Ideas and visions of the pragmatic web (see Hakkarainen et al., 2009 for references) guide one to acknowledge that social practices of using technology play a crucial role in cultivation of technology-mediated inquiry learning. From this perspective, the present discourse of ICTs is biased in terms of focusing, as the term implies, either on the information-transmission genre or social-communication genre. Otherwise attractive visions regarding the emergence of collectively intelligent metaweb (Nova Spivack1) are “flat” because it is assumed to arise from increased information connectivity, on the one hand, and social connectivity, on the other hand. The pragmatic web guides one to examine social practices, related to the historical-developmental use of technology, as the topography or third dimension of the metaweb revealing an extremely rough terrain of the surface. Learning to use a new technology initially requires so large investment of both personal and collective efforts that it can be compared with climbing to the top of a steep mountain; after going through such an extra-ordinary effort the participants may be reluctant to start climbing to another mountain without very good reasons for doing so; it is always easier just to slide down the familiar hill. Personal appropriation of even relatively simple technology, such as email, is initially tremendously challenging because it requires appropriating new social practices and changing the associated chronotope of activity. Moreover, the challenge of collaborative technology is to get a whole heterogeneous and often unwilling community to climb to a mountain rather than to do it individually, only by themselves. The exact route cannot be planned beforehand; participants need to learn improvisationally negotiate partially unforeseen challenges and obstacles. The transformation is difficult

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because there are no ways of moving straightforwardly from present to new practices; an iterative and expansive process of transforming practices, gradually, step by step in the desired direction is needed (Engeström, 1987). One cannot change all aspects of activity at ones, only try to change this or that aspect, see what happens, and expand those initially ephemeral innovative aspects of activity that appear to support directed evolution of practices. Gradually, new, initially ephemeral patterns of activity may emerge through iterative efforts of the participants and become selectively consolidated and transformed to established shared patterns of activity. The notion of chronotope appears useful because it assists in understanding how complex and dynamic semiotic spaces are inherently linked with shared social practices; the challenge is to create methods and approaches that allow investigating such processes. Epistemic mediation, chronotope, and knowledge practices appear, then, to be aspects of technology mediated learning, having three mutually dependent aspects which may be characterized as follows: 1) In order to transform technological artifacts to instruments of inquiry, expansive development of prevailing knowledge practices is needed. 2) When adequate, the prevailing knowledge practices guide and channel the participants activities in a way that facilitate epistemic mediation (making epistemic mediation as a social practice). And 3) finally, successful pursuit of technology-mediated learning involves collaborative emergence of a new chronotope, embedded on evolving knowledge practices, that elicits collaborative creation of knowledge.

Discussion
The sociocultural foundations of knowledge-creating inquiry were addressed in the present paper so as to examine the role of epistemic mediation in the chronotope of technology-mediated learning. We argued that cognitive augmentation and cumulative expansive stimulation provided by epistemic mediation play a crucial role in complex cognition; consequently, it is of strategic importance to put corresponding knowledge practices in the center of technology-mediated learning. From the sociocultural perspective, it is essential to provide students tools that allow creating shareable external digital artifacts for supporting collective activity; Bereiter and Scardamalia’s (2006) research and development of collaborative technologies and associated practices of knowledge building that allow collectivization of inquiry has played a crucial pioneering role in this regard. It appears that CSCL environments are children of hybridization in terms of providing material technology for sustained working with shared digital (but yet materially embodied) artifacts. As mentioned above, integrating CSCL technologies as instruments of participants’ activity is a developmental process of its own right (Béguin & Rapardel, 2000); cultivation of innovative inquiry practices within a learning community is not possible without sustained iterative and expansive efforts of cultivating a chronotope that channel spatiotemporally the participants’ effort in a way that elicit advancement of inquiry. Technology enhancement of learning is always mediated by chronotope of transformed social practices. Hassan (2003) clearly explains the sociological consequences that ICT’s generated “chronoscopic” time, i. e. a digitally compressed and accelerated time. The use of specific external tools in learning practices appear to generate a new space-time, a new chronotope, that on the one hand can amplify the potentiality of human learning and on the other hand require subjects to restructure their thinking and their learning by the effective integration of the external tools into their learning practices. The participants have to be able to personally as well as collectively align their epistemic activities with technology-mediated pursuit of collaborative inquiry.

In human sciences the research methods employed appear to create the phenomenon, i.e., research object, of which investigators seek to provide an account. We investigators have a reductionist tendency to address only those phenomena that are easily accessible with readily available research instruments. Many studies of CSCL are biased because either focusing on shallow here-and-now interaction or analyzing mere ideas (contents of epistemic artifacts) created by participants. Consequently, only a few investigations have revealed the heterogeneity, hybridity, and multi-modality of enacted CSCL practices or provided rich and multi-faceted descriptions of the longitudinal emergence of chronotopes of innovative inquiry. Instead, we have descriptions of poor CSCL implementations in which a novel chronotope did not have time to emerge as well as static analyses of mature inquiry cultures without accounting for the developmental process at all. In order to provide an account of collaborative emergence of the chronotope involved in practices of knowledge-creating inquiry, multi-level longitudinal data have to be collected; such data involve real-time video data of enacted classroom practices, screen recordings of ICT-mediated inquiries, contextual sampling of students and teachers’ reflective self-report (e.g., project diaries), analyses of contents and processes of artifacts at CSCL environment’s database, and possible pre- and post-test measures. The present investigators’ preliminary experiences of collecting and analyzing such multi-level data indicate the emergence of whole new CSCL phenomena that were invisible when addressing mere isolated aspects of chronotope.

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