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Chapter #: Computer-supported collaborative learning: instructional approaches, group processes and educational designs

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Abstract

This chapter reviews research on computer-supported collaborative learning (CSCL). Its scope includes learning that takes place face-to-face, remotely, and in blends of face-to-face and remote activity. It considers learning in groups of various sizes (from dyads to learning communities). It considers a range of approaches intended to promote and support collaborative learning, including instructor-led methods, scripted methods and methods that open up space for the autonomous, creative, productive work of the collaborating learners.

The chapter builds upon and updates related chapters in previous versions of the handbook. It provides the reader with links to broad-based, landmark reviews and summaries of this area and some of the core texts on the role of technology in computer-supported collaborative learning. The chapter reviews selected research contributions from the last five years, identifying some emerging themes and highlighting important unresolved issues. It provides a conceptual orientation to the nature and potential educational benefits of CSCL. It summarises research results concerning: real-time (synchronous) CSCL, blended designs for CSCL, and CSCL using Web 2.0 technologies. It identifies some key issues in the methodology of CSCL research and also provides an

overview of recent research on CSCL design using scripts and design patterns.

Keywords

Computer supported collaborative learning (CSCL)

Computer-supported collaborative learning (CSCL) refers to circumstances in which computer technology plays a significant role in the way in which students work together to maximise their own and each other's learning.

Networked learning

Networked learning is learning in which information and communication technology is used to promote connections: between one learner and other learners, between learners and tutors; between a learning community and its learning resources.

Collaboration script

A collaboration script can be an explicit description or an internal resource that helps someone participate successfully in a CSCL activity, typically it focuses on some combination of role definitions and guidance about the sequence of activities to be undertaken.

Design pattern

A design pattern captures and shares design experience in a structured text which: states the essence of a design *solution*, links it to the *contexts* in which the solution is applicable, and provides a rationale that connects solution, problem and context.

Participation

Participation, taking part in or sharing an activity, is strongly associated with social and situated views of learning and more recently with Web 2.0, but participation in group activity or via a supportive technology is not sufficient to ensure productive collaboration.

Chapter #: Computer-supported collaborative learning: instructional approaches, group processes and educational designs

Introduction

This chapter provides an introduction to the field of research on computer-supported collaborative learning (CSCL). It builds on related chapters in previous versions of the handbook (e.g. Romiszowski & Mason, 1996; 2004; Johnson & Johnson, 2008; Satwicz & Stevens, 2008). It also provides links to broader-based reviews of research on collaborative learning (e.g. Slavin, 1990; Webb & Palincsar, 1996; Johnson & Johnson, 1999) as well as to some key texts on CSCL (e.g. Koschmann, 1996; Dillenbourg, 1999; Steeples & Jones, 2002; Koschmann, Hall & Miyake, 2002; Strijbos, Kirschner & Martens, 2004; Stahl, Koschmann & Suthers, 2006; Dirckinck-Holmfeld, Jones & Lindström, 2009). That done, the chapter provides a review of selected research contributions from the last five years, identifying some significant themes and areas of opportunity for future research.

The chapter's scope includes CSCL that takes place face-to-face (F2F), remotely, and in various blends of F2F and remote activity. It looks at synchronous (real-time) as well as asynchronous interaction. It covers learning in groups ranging in size from dyads to learning communities. The chapter also reviews recent literature on the analysis of group processes in CSCL. Its closing sections focus on design for CSCL, with an emphasis on collaboration scripts and design patterns.

Collaborative learning

Johnson & Johnson (2008) distinguish co-operative and collaborative learning from competitive and individualistic learning. In individualistic learning, students work by themselves to accomplish learning goals. In competitive learning situations, they work against each other to achieve a goal (such as a rank in the class). Johnson & Johnson use the terms co-operative and collaborative learning interchangeably, to denote situations in which students work together to maximise their own and each other's learning. Dillenbourg (1999) and others distinguish between co-operative and collaborative learning. *Co-operative* learning is used to denote situations in which students (can) divide up a group task and tackle the parts with a substantial element of independence. *Collaborative* learning requires the group to complete the task together, through dialogue and joint action. Collaborative learning provides learning opportunities that are side-stepped in co-operative learning. Guidance from the instructor, but also task design, can make the difference between a learning situation being tackled collaboratively rather than co-operatively - or even, individualistically (Paulus, 2005).

CSCL

CSCL refers to situations in which computer technology plays a significant role in shaping the collaboration. The term has had some currency since the late 80s/early 90s, though there is a slightly longer history of educational research into (co-present) group work with computers (e.g. Eraut & Hoyles, 1988) and into networked learning using online forums and email (e.g. Levin et al., 1987).

In some cases, CSCL involves learners who are working at a distance from each other and the computer technology is their primary means of interacting, providing valuable flexibility in the use of time and space. But 'CSCL' is also used to describe situations in which learners are co-present, as long as the technology plays a significant role in shaping the nature of their interactions with each other and supporting their collaborative

activities. It is also important to recognise that some designs for CSCL include situations that interleave periods of working at a distance with working F2F, and may include mixtures of synchronous and asynchronous collaboration (e.g. a live F2F event, followed by an online discussion).

Technology can play a variety of roles in CSCL, e.g. it may provide a visual representation of the task or product on which the students are working, or of some key aspects of their collaboration process (e.g. Suthers & Hundhausen, 2003; Kay et al., 2007). Computer support may also take the form of scaffolding – as when structuring devices are used to help with the development of argumentation and/or in knowledge-building (e.g. Marttunen & Laurinen, 2001; Lu et al., 2010; Scardamalia & Bereiter, 2006).

Networked learning

"Networked learning" is "learning in which ICT…is used to promote connections: between one learner and other learners, between learners and tutors; between a learning community and its learning resources" (Goodyear et al., 2004, p1). The term is sometimes used as a synonym for forms of CSCL that largely or exclusively involve remote rather than face-to-face collaborations. Within the literature of networked learning (see e.g. Steeples & Jones, 2002; de Laat, 2006; Dirckinck-Holmfeld, Jones & Lindstrom, 2009; Dirckinck-Holmfeld, Hodgson & McConnell, 2011) there is a sense that the term connotes collaborations involving medium to large numbers (tens to hundreds of participants, rather than (say) dyads).

The educational potential of CSCL

Meta-analyses and systematic reviews have established the general case that the outcomes of collaborative learning are superior to those of individualistic and

competitive learning situations (Slavin, 1990; Webb & Palincsar, 1996; Johnson & Johnson, 1999; Hattie, 2009). Johnson and Johnson (2008) concluded that face-to-face CSCL outperforms comparable individualistic and competitive technology-based learning situations – whether the outcomes measured are the volume or quality of work accomplished, mastery of factual information, ability to apply factual knowledge, or success in problem-solving. Collaboration can expose each learner to multiple perspectives on, and explanations of, phenomena. It can provoke belief revision, and provide external monitoring of, and feedback on, problem-solving performance.
For face-to-face CSCL, there is evidence to suggest that dyads and small groups perform better than larger groups (Lou, Abrami & d'Apollonia, 2001; Lou, 2004) – within larger groups there are fewer opportunities for each student to articulate and examine their own beliefs. However, this potentially detrimental size effect can be countered by good design and/or group moderation (see scripting section below).

This body of research, impressive though its findings may be, tells less than the whole story about CSCL. For example, it applies a paradoxically restricted sense of learning – through testing the *acquisition* of knowledge by *individuals*. There is more to learning than the acquisition metaphor implies (Sfard, 1998; Paavola et al., 2004). Much research and practice in CSCL has roots in Vygotsky and is inspired by ideas of learning in social interaction and knowing as distributed across minds, tools and artefacts. Opportunities to participate in social practices are valued in their own right, irrespective of what might later be measurable as an individualistic learning outcome. CSCL in this view is concerned with meaning, and meaning-making, mediated by digital artefacts in the context of joint activity (Koschmann 2002, Jones et al. 2007). The opportunity to participate in core practices of the times – such as collaborative knowledge-building – achieve an intrinsic value (Bereiter, 2002; Paavola et al 2004; Stahl, 2006).
Consequently, a significant vein of CSCL research has focussed on argumentation skills

– the ability to participate in an argumentative discourse; to make defensible claims (providing warrants, qualifications, etc); to test the claims of others, draw appropriate inferences, etc (e.g. Marttunen & Laurinen, 2001; Andriessen, Baker & Suthers, 2003; Weinberger & Fischer, 2006; Scheuer et al, 2010; Weinberger, Stegmann & Fischer, 2010). Participation in CSCL does not automatically confer the benefits of learning to argue, or learning through arguing. It is not enough for a student to be allocated some group work, or for them to have access to some supportive technology. Rather, the situation in which they find themselves needs to provoke certain kinds of productive social interactions, which in turn stimulate appropriate mental activities with some chance of lasting benefits (Dillenbourg, 1999; Goodyear, 2002; Wegerif, 2006; Dillenbourg, Jarvela & Fischer, 2009; Summers & Volet, 2010).
This implies a pro-active role for the teacher/instructor and/or well-executed up-stream design.

CSCL in real time: face-to-face and online

Much of the theory-driven research carried out in CSCL has involved asynchronous collaboration, using data from discussion boards in tertiary, online learning environments. More recently, some attention has been given to CSCL in real time: face-to-face (F2F) CSCL and (usually remote) synchronous online CSCL.

Face-to-face, synchronous CSCL

F2F CSCL research investigates collaboration as it occurs around a shared piece of technology or educational program, such as mobile devices (e.g., Zurita & Nussbaum, 2007), virtual worlds (e.g. Girvan & Savage, 2010), simulation models (Sins, Savelsbergh, van Joolingen, & van Hout-Wolters, 2011), interactive whiteboards (e.g.,

Kershner et al., 2010; Warwick et al., 2010), or interactive tabletop devices (e.g., Falcao & Price, 2010). The collection and processing of data associated with F2F CSCL can be time-consuming compared to that associated with synchronous, online CSCL. Recent studies such as those using a MUVE (Thompson, Kennedy-Clark, Markauskaite, & Southavilay, 2011) use video to capture the computer screen, computer usage, gestures between students, and the direction that the students face, in addition to high quality audio, and log files of sequences of actions on the computers. In addition, the artifacts produced, or around which collaboration occurs, are also collected (Jeong, Chen, & Looi, 2011). These additional streams of data are adding to our understanding of CSCL environments, and the roles that the tools play. Studies using specific tools do have implications for other forms of CSCL. These include the ways in which students are able to collaborate around such devices, and the role of the instructor, in particular scaffolding techniques and the design of activities (Kershner et al., 2010), and their presence in student groups (Warwick et al., 2010).

The Interactive Whiteboard (IWB) provides learners with a different perspective on their learning environment due to its large screen and orientation. Kershner et al. (2010) investigated "how the IWB's affordances to support learning were employed by the children to *think collectively*" (p. 362). They used Mercer's (2004) *sociocultural discourse analysis* as a theoretical lens through which to view the experiences around the collaboration – identifying disputational, cumulative and exploratory group talk. The continued focus on exploratory group work was very important in achieving productive interaction – without collaboration skills, students had trouble interacting at the IWB, and this affected learning outcomes. Specifically, it was found that students need a joint understanding of the task, they need positive motivation and to take responsibility for their own learning, and they need to engage in active support for each other, which relate more to general classroom dynamics than to the IWB.

Productive collaboration was also disrupted by technical difficulties (Kershner et al., 2010). Some groups, when faced with technical issues, engaged in discussion that helped to bond the group and developed a collective self-efficacy. Falcao & Price (2010) address this issue of interruption, or interference, in collaborative processes suggesting interference could provided a trigger for argumentation and co-construction of knowledge. Their results showed that what could be thought of as 'ideal' collaboration – organised, coordinated and planned interaction –meant that students reduced the level of exploration, and the moderator was required to stimulate further inquiry.

The design of tasks within which students collaborate around a shared device is important when considering the success of CSCL in these classroom environments. For the IWB, recommended tasks are those that allow students to engage with screen objects, physically engage with the screen, take control of elements of the lesson, represent ideas, access alternative possibilities, or refocus and refer to previous knowledge (Kershner et al., 2010; Warwick et al., 2010). Similarly, for tabletop learning environments, design of tasks that take advantage of the affordances of the tool – using multiple resources, simultaneous multiple inputs, dependency on one physical-digital resource, dynamic digital feedback and shared visual field, and the creation of opportunities for spontaneous and productive collaborative situations have been recommended (Falcao & Price, 2010).

Synchronous Online CSCL

Synchronous online CSCL has features of both F2F and asynchronous CSCL. Research has focused on aspects of understanding and managing the synchronous CSCL environment, such as decision-making (Reimann et al., 2009) or social presence (Weinel et al., 2010). Some work has focused on the way in which learners co-construct their shared understanding of working in CSCL environments (Holliman & Scanlon, 2006). Some research focuses on the role of the moderator in synchronous e-discussions,

informing moderation techniques or development of tools to support moderation (see De Groot et al., 2007; Asterhan & Schwarz, 2010; Wichman et al., 2009). In order for synchronous online collaboration to be successful, the role of the moderator is vital, and challenging (Wichman et al., 2009). The design of the collaborative tasks is also important (Holliman & Scanlon, 2006).

Teacher moderation is an important issue in synchronous environments because teacher support for students relies on online knowledge about collaborative discussions (Asterhan & Schwarz, 2010). The authors, used Lund's (2004) taxonomy of human supportive roles in CSCL and suggest a distinction can be made between generic and content-specific instruction within pedagogical support. They found that students expect moderators to scaffold their reasoning and their knowledge construction and keep the discussion focused. Overall, students expected moderators to be actively involved in the discussion, while still allowing construction of knowledge by the students. Asterhan & Schwarz (2010) were able to identify two types of moderator scaffolding prompts – generic (low content) and non-generic (content-specific). They decided that Lund's distinctions were not useful for analysing discrete moderation moves within a discussion and that the non-generic scaffolds were more successful. It may be that other purposes/tools may be better suited to generic scaffolds, but if it is the case, then this would be a design decision that needs to be made. They conclude that instructional practices used effectively in other formats – asynchronous or F2F – should not be simply transferred.

Tools have been developed to aid teachers in managing synchronous learning environments, and some of this work also generates real-time data that can be used for research and support. Asterhan & Schwarz (2010) used a tool called Digalo, in which the communication is visually organised and threaded. The ARGUNAUT approach (DeGroot et al., 2007) supports moderation by automatically monitoring ongoing discussion while

simultaneously deriving situation indicators. Trials of awareness support tools (Wichman et al., 2009) found them to be helpful during the moderation of multiple e-discussions, and allowed better understanding of the students' activities. Some research is investigating ways to automatically infer when students are collaborating from the application and audio traces of interaction (e.g. Martinez et al., 2011).

Similarities in the issues that face those managing CSCL environments exist across the F2F and synchronous online settings discussed in this section. The role of the instructor is vital, the design of the tasks is important, and matching appropriate tasks with expected outcomes is necessary in order to obtain successful learning outcomes.

Blending face-to-face and online collaboration

There are good educational arguments for *well-designed* combinations of face-to-face and online collaboration, where the logistics of the learners' study situation allows (So & Bonk, 2010). Reisslein, Seeling & Reisslein (2005) report that students who have been asked to work in online groups state that they would prefer to be able to meet F2F beforehand. It is not uncommon for "blended" designs to involve a F2F meeting at the start, a period of online collaboration, and a final F2F meeting for purposes of group presentation, assessment and project closure. Other designs can involve more frequent meetings – for example, with a weekly F2F discussion followed by a week-long online discussion (Ellis et al., 2006; 2007) or with computer-supported PBL groups that meet once or twice a week and co-ordinate their group activity online in between meetings (e.g. Lu et al., 2010). Further design variations blend synchronous and asynchronous online activity. For example, Michinov, Michinov and Toczek-Capelle (2004) show how synchronous chat sessions can be used to help create a sense of belonging at the start of an online program, as a substitute for F2F kick-off meetings. Conversely, Dietz-Uhler &

Bishop-Clark (2001) found that initial online discussions had a beneficial effect on subsequent F2F collaborative work. Michinov & Michinov (2008) have investigated the effects of a *mid-point* F2F meeting, premised on the view that the mid-point of an online program of collaboration can be a period of instability and change. They found beneficial short-term effects on online participation just after the F2F meeting, but then saw a decline in task-oriented interactions and a rise in negative affect.

CSCL with Web 2.0 technologies

CSCL faces a challenge in the context of new technologies described as Web 2.0 because Web 2.0 involves large scale network effects and the ability to interact in, and contribute to, large groups (Kafai and Peppler 2011). A practice perspective on Web 2.0 in CSCL was outlined by Dohn (2009) in this way:

- Collaboration and/or distributed authorship
- Active, open-access, "bottom-up" participation and interactive multi-way communication
- Continuous production, reproduction, and transformation of material in use and reuse across contexts
- Openness of content, renunciation of copyright, distributed ownership
- Lack of finality, "awareness-in-practice" of the "open-endedness" of the activity
- Taking place on the WWW, or to a large extent utilising Web-mediated resources and activities

The idea of Web 2.0 is intentionally imprecise and the definition provides a delimited core and a less precise periphery and it is often clarified by illustration, using contrasting

examples of the Web and Web 2.0. Despite this lack of clarity Web 2.0 is a term that has been absorbed into CSCL literature (for example Glassman and Kang 2011, Dohn 2009, Cress and Kimmerle 2008).

Many Web 2.0 technologies blur the distinction between synchronous and asynchronous communications by incorporating both features in a single interface. Web 2.0 however is primarily an asynchronous medium because asynchronous communication is most amenable to scale. Web 2.0 places emphasis on user-generated content and participation, focused on the generation, manipulation and sharing of content. Applications of Web 2.0 in education have taken a variety of forms and include a number of different media. Empirical studies have reported on the collaborative use of blogs (Ducata and Lomika 2008, Farmer et al. 2008), wikis (Minocha and Thomas 2007), Virtual Worlds (Konstantinidis et al 2010), and mobile social media (Lewis et al. 2010). For a recent review, see Dohn (2010).

An area of connection between the literature on Web 2.0 and collaborative learning has been the focus on participation and participatory culture in Web 2.0 environments (Jenkins 2009). Clear links have been drawn between Web 2.0 technologies and the participation metaphor of Sfard (1998), the knowledge building approach of Scardamalia and Bereiter (2006), and the knowledge creation metaphor of learning found in Paavola and Hakkarainen (2005). Participation was strongly associated by Sfard (1998) with the emergence of social and situated views on learning, and the ideas of learning as a process, legitimate peripheral participation, and learning in a Community of Practice (Lave and Wenger 1991). However Sfard counseled against merging the participation metaphor with a social view of learning, noting that the more psychological views of collaboration suggested a process of internalisation that sat more comfortably with an acquisition rather than a participation metaphor (Sfard 1998).

Dohn argues that Web 2.0 and educational practices implicitly represent divergent understandings of knowledge and learning and that education implicitly embodies the acquisition metaphor whereas Web 2.0 embodies the participation metaphor (2009). This opposition between Web 2.0 and education is drawn too sharply and education, as Sfard noted, requires the use of both participation and acquisition metaphors. Web 2.0 can be seen as tilting the balance towards participation but in a way that is not in contradiction with educational practice. For example Lewis et al. (2010) argue for the application of social theories of learning for design in participatory media. They argue that the power of social media for learning may lie in their potential to foster collaborations, on a scale and in tighter time cycles than has been seen before (Lewis et al. 2010). On this view, the logic of Web 2.0 can be mobilised for educational purposes by using crafted interactional affordances to support shared experiences and meaning-making.

Web 2.0 poses a challenge to CSCL in the way it places a priority on large scale network effects. The architecture of participation is an architecture of scale and Web 2.0 suggests that the value of a service increases with the number of users that share that service. Design in Web 2.0 may take place at a meta-level in which systems allow users to create content but in addition users can also modify the behaviour and components of the system at the time of use. Meta-design of this type takes place at the level of the social and technical infrastructures in which participatory cultures and new forms of collaboration take place (Fischer and Giaccardi 2006). CSCL has often concerned itself with tool and application development, whereas Web 2.0 processes would suggest changing focus to whole infrastructures and the provision of large scale or universal services. Jahnke (2009) observed that Web 2.0 applications "transform social systems (e.g. social groups, universities) into socio-technical systems, where socially and technically supported relationships are highly interwoven" (Jahnke 2009 p287). Key issues for future work in CSCL in relation to Web 2.0 concern infrastructures and the

levels between micro-level interactions and macro-level social and technical conditions (Jones et al. 2006; Jones and Dirckinck-Holmfeld 2009).

Assessing group processes

In the last five years, our ability to measure, and to appreciate the complexity of, the processes of CSCL has benefited from advances in methodologies used and in computational power. As should be expected with the uptake of new methods of analysis, there are concerns about the rigor with which this research is conducted (De Wever, 2006). Within CSCL particularly, research examining the processes involved suffers from an incoherent approach: each coding scheme used builds on a particular element of a different theory of learning and cognition. These theories include argumentation (Weinberger & Fischer, 2006; Ding, 2009), relationships between interactive, cognitive and discursive dimensions of knowledge-building (Schrire, 2006), knowledge sharing, knowledge construction and knowledge creation discourse modes (Van Aalst, 2009), or designing for co-construction of knowledge and negotiation of meaning, measuring participant dialogue (Hull & Saxon, 2009). Research addresses both synchronous (Ding, 2009) and asynchronous collaboration (for example, Weinberger & Fischer, 2006; Hull & Saxon, 2009), but few address both. The participants examined in this field of research are learners at various stages, including university students (Weinberger & Fischer, 2006), teachers (Hull & Saxon, 2009) and high school students (Ding, 2009). The units of analysis are different in each study, because they depend on the question asked (Schrire, 2006). Some studies segment the data over multiple levels (for example, Weinberger and Fischer (2006), and others use additional elements to make sense of the process (such as the artifacts produced by collaboration (Ding, 2009)). Processes of collaboration do tend to be measured by content analysis of chats or discussion boards, and standard reporting

of this type of analysis is followed (De Wever et al., 2006). Some also analyse log file data (Reimann, 2009). Very few studies replicate other work or even use the same coding scheme, and there is no over-arching theory within which all can be placed. The findings sit disjointed, and the reader is left to imagine how they may fit together. Clarà and Mauri (2010) begin to address the problem of reconciling studies, using an individual, group, context framework. They maintain that the differences are necessary and important and that the tensions provide the space for further development in CSCL. Regardless of the approach, to study processes in CSCL involves choices of theory, measures, and analysis.

Some of the research reviewed for this chapter incorporates multiple measures of process, such as that by Weinberger & Fischer (2006), Schrire (2006), Van Aalst (2009), Ding (2009), and Evans, Feenstra, Ryon & McNeill (2011). Such studies allow the identification of interaction effects (Weinberger and Fischer, 2006). Schrire's work indicates a relationship between collaborative interaction and socio-cognitive processes, discovering interaction pattern types, which she suggests, could be used as indicators for characterizing knowledge building. Ding's (2009) study identified individuals' patterns of knowledge elaboration and used these to explain the dyad's dynamics and the learning outcomes. The identification of interactions between multiple processes and patterns adds to our knowledge of how collaboration tools, such as scripts, work and in turn, inspires discussions around designing effective CSCL environments. At this point, however, researchers are finding patterns to explain learning outcomes (Schrire's instructor- and synergistic-centred patterns within discussion board threads, Ding's three patterns of knowledge elaboration), rather than empirically testing the relationship between them. An issue when using multiple measures is how to visualize the way in which the measures fit together. A tool designed to do this is Tatiana (Trace Analysis Tool for Interaction ANAlysis) (Dyke, Lund, & Girardot, 2009). The group has demonstrated the way in which one data set was analysed from the perspective of knowledge building, the uptake

of representational practices, and a cognitive perspective of group understanding (Dyke et al., 2011). The main advantages of this tool are concerned with identifying similarities and differences between the analytical approaches, rather than finding links between them. Multimodal coding is the term used by Evans et al. (2011), who incorporate cognitive, perceptual, verbal and non-verbal elements to examine children's contribution to knowledge building activities. They use a linguistic annotation software tool called ELAN as well as excel, allowing them to visualize the complex data over time.

Accounting for temporal patterns in processes of learning is a recent development in this field. Reimann's formative paper (2009) discusses the use of data, sequence and process mining to identify patterns for cases in which the collaborative process has been designed. These event-based approaches can sit alongside variable-centred approaches, adding a layer of information to our understanding of processes that focuses on long-term (days, weeks, months) changes in groups and takes into account the order of events. Reimann (2009) goes beyond the individual/group/context and also accounts for the group's learning history. The event centred approach allows changes in group processes that are not easily quantified, such as when a member leaves a group, to be taken into account during the analysis. While some researchers have applied methods of analysis to process data such as heuristics mining (Reimann, Frerejean, & Thompson, 2009), others question the likelihood that processes in CSCL environments should be fit to linear, consistent models of interaction (Goggins, Laffey, & Amelung, 2011). Other methods used include Lag-sequential analysis to identify transition patterns between process categories (Kapur, 2011), and multilevel, ordered logistical regression to create an explanatory model (Wise & Chiu, 2011). Factoring in of time, and the acknowledgement that group processes change over time, has inspired a range of exciting new research questions and methods.

The purpose of researching the processes involved in CSCL is to be able to relate

processes to learning outcomes (Schrire, 2006; Weinberger & Fischer, 2006), to design learning environments so as best to encourage appropriate CSCL (Schrire, 2006; Van Aalst, 2009), and once armed with an appropriate pedagogy, to further provide instructors with the tools necessary to manage these environments in real-time (Schrire, 2006). Thus far the studies investigating processes in CSCL have been carried out in narrow fields (for example Weinberger & Fischer, 2006), and the processes have to be manually coded and analysed, which is time-consuming (Weinberger & Fischer, 2006; Reimann, 2009). Links with learning outcomes tend to stand-alone, not adding to a larger theory.

Also relevant to this discussion is the use of social network analysis in CSCL and networked learning (e.g. Haythornthwaite and De Laat 2010, De Laat & Lally 2004, De Laat et al 2006, De Laat et al 2007). Social networks are composed of nodes or actors and the ties or connections between them. Nodes can be individuals, organizations, communities or other kinds of collectives and in principle actors or nodes can be of different types, including non-human actors. Currently there is little work that includes non-human actors or hybrid forms such as humans interacting through networks that include other non-human nodes. From a social network perspective the research interest is in the nature of ties between participants and whether they are weak, strong or latent (Jones et al 2008, Haythornthwaite 2002). However it is not always clear what might be sufficient to say there is a tie between pairs (De Laat and Lally, 2004). Partially in response to this De Laat (2006) has argued for a combination of social network analysis with a time line analysis to understand the relationship between engagement with learning and peer support and the ways they evolve.

Research in this area needs replication of existing studies to validate instruments with larger, empirical studies (De Wever et al., 2006), and a focus on hypothesis testing (De Wever et al., 2006; Reimann, 2009). Further to this, Reimann (2009) calls for shared online collections of annotated sequence data so that they can be analysed by many, with

a variety of methods and tools. Exciting breakthroughs are being made, such as the automatic identification of reasoning displays and idea co-construction contributions in speech data (Gweon, Agrawal, Udani, Raj, & Rose, 2011). Gweon et al have been able to show that a statement can be classified as either reasoning or non-reasoning, not based on textual input, but on acoustic and prosodic features of the speech, such as levels of pitch, intensity of speech, amount of silence and duration of speech. Examining the processes of CSCL contributes to the development of theory in the learning sciences, but overarching frameworks are still sorely lacking.

Designing for CSCL

Persico & Pozzi (2010) boil down CSCL design to three crucial elements: tasks, teams and time. To these we would add tools – making a 'four Ts' model. Design may specify the nature of the task, how it could be broken down into sub-tasks and how these might be scoped and sequenced, how the work could be divided up amongst team members, the internal structure of a team (size, heterogeneity etc.), how team members might interact, what tools and resources they will need (Goodyear, 2005; Laurillard, 2008; Pozzi, 2011). Design theorists of different persuasions may vary the verbs in the previous sentence: some insisting on 'might', 'could' or 'may' while others prefer 'ought' or 'should' or 'must' (c.f. Dillenbourg & Tchounikine, 2007).

Collaboration scripts

A script for collaboration may capture a number of these design elements, but is typically held to focus on some combination of (a) role definitions, (b) guidance about the sequence of activities to be undertaken by each of the role-holders (O'Donnell & Dansereau, 1992; De Wever et al., 2010). Interest in the educational benefits of

collaboration scripts flows from a recognition of the fact that spontaneous interaction within F2F learning groups rarely results in the depth or richness of cognitive engagement that is necessary if the potential benefits of collaboration are to be secured (e.g. King, 2007).

One can distinguish a scale-level in scripting: for example, designs that focus on roles and activity sequences are sometimes referred to as 'macro-scripts', to distinguish them from 'micro-scripts' that are intended to prompt a single move or a small number of turns in (say) an argument (Dillenbourg, Järvelä & Fischer, 2009; Morris et al., 2010). Scale considerations have also been explored in the analysis of roles. For example, Strijbos & de Laat (2010) distinguish between micro, meso and macro roles, where the first is (normally) associated with carrying out a single task, the second with carrying out a cluster of tasks, and the third with a more generalised stance or attitude towards participation in a collaborative activity. Scripts can be thought of as either external, internal or both. That is, a script may be produced as an explicit description or prescription for some collaborative activity; or it may be an internal (metacognitive) resource that helps someone participate effectively in a CSCL activity. People may learn to become better at CSCL by internalising scripts that they first encounter as external representations (Kollar et al., 2007).

Research on scripted collaborations in CSCL has created a substantial body of findings (Fischer, Kollar, Mandl & Haake, 2007; Dillenbourg et al, 2009; Weinberger et al., 2009; Weinberger, Stegmann & Fischer, 2010). Within this literature, there is an emerging view that some scripting is better than no scripting, but that over-use or over-reliance on scripts can be counterproductive (Dillenbourg, 2002; Makitalo et al., 2005). Tighter resolution of this argument depends upon what outcomes are valued. For example, over-scripting might be held to inhibit transfer, or the emergence of self-regulatory abilities, even if it boosts immediate performance on the task at hand or as captured in post-tests of

knowledge acquired (Kapur, 2008; Diziol et al., 2010; Strijbos & Weinberger, 2010; see also Gressick & Derry (2010), who place particular value on emergent patterns of leadership in online groups).

However, even in relation to these 'shorter range' targets, scripting does not guarantee success. For example, Weinberger et al (2005) tested the efficacy of two types of scripts: social scripts (which aim to guide students about how they should interact with each other in a CSCL situation) and epistemic scripts (which aim to help students focus on and complete each stage in an epistemic task). In short, epistemic scripts focus on the "what" of a learning task; social scripts focus on the "how". Such scripts may be implemented and used in a variety of ways, so it is hard to generalise about their intrinsic qualities. However, while Weinberger et al were able to show positive benefits with their social scripts, they found deleterious effects with their epistemic scripts.

While research on the effects of collaboration scripts is still active, it is clear that effective scripting is a complex, dynamic problem that is unlikely to be tackled successfully through the imposition of rigid, *a priori* designs. This makes (software-based) dynamically adjustable scripting/scaffolding of collaboration a particularly interesting area for future R&D (see e.g. Dillenbourg & Tchounikine, 2007; Diziol et al 2010). In a complementary way, it also favours further R&D on tools that groups can themselves use to visualise and monitor their own collaboration processes, and negotiate adjustments to working methods accordingly (Kay et al., 2007; Bodemer & Dehler, 2011). An associated line of R&D in the area of real-time orchestration of collaborative learning (by classroom teachers) is similarly investigating the ways in which tools and artefacts in the environment can help with the monitoring and management of CSCL processes (see e.g. Alavi et al., 2009). Underpinning this, we need a way of theorising the relationships between learners' agency and the structuring effects of tasks and tools, such that instructors and designers can provide appropriate forms and levels of support and

guidance (Goodyear, 2005; Stubbs et al., 2006).

Design patterns and pattern languages

Design patterns and pattern languages have emerged as an area of interest in CSCL in the last decade. A design pattern is a structured text which: states the essence of a design *solution*, linking it to the *contexts* in which the solution is applicable, and providing a rationale that connects solution, problem and context (Goodyear & Retalis, 2010). It is a way of capturing and sharing design experience. A pattern language is a structured set of patterns aligned with the requirements of a complete design task. Design patterns and pattern languages have been created in both networked learning (e.g. Goodyear, 2005; Goodyear, de Laat & Lally, 2006) and CSCL contexts (e.g. Hernandez-Leo et al., 2010; Villasclaras et al., 2009). They are seen as ways of supporting the work of 'teacher-designers', particularly in the area of specifying CSCL tasks and roles.

Hernandez-Leo et al (2010) show how proper consideration of the *structures* in a pattern language (the types of relationships obtaining between patterns) can provide an effective basis for carrying out educational (re)design work. They identify a number of connecting rules that can be used to combine, or decide between, patterns. For example, some patterns *complete* or "embellish" other (higher level) patterns. In other cases, patterns can be seen as *complementary* (use two or more) or as *alternatives* (use just one). Again, some patterns are *specialisations* of more general design ideas, existing at the same level of aggregation. To this we would add the reciprocal of "complete" – to point out that some patterns function as the *context* for lower level patterns (which, in turn, complete them). Hernandez-Leo et al (2010) identify a range of 18 patterns for CSCL scripting, including patterns which help implement relatively well-known CSCL designs such as JIGSAW.

Goodyear, de Laat & Lally (2006) show how collections of design patterns can become

core parts of a shared knowledge base for a community of practice (e.g. teacher-designers involved in networked learning). The argument depends upon a sense of patterns as offering what the authors call an "actionable locus" – a place where evidence from the analysis of research data, theorising, previous praxis and practical strategies come together.

To date, there has been rather little research evaluating the usefulness of design patterns for CSCL, beyond reflective case studies from the pattern-writers' own teaching. This could take one or both of two possible foci – (i) the effectiveness and efficiency of the design process; (ii) impacts on learning (Rusman et al., 2009). Given the rapid expansion of interest in the use of educational design patterns more generally, the need for research of this kind is becoming urgent.

Conclusions and further research

In this chapter we have provided an overview of recent research in computer-supported collaborative learning (CSCL), paying particular attention to instructional, group process and design issues. Reviewing research in recent years, we see a strong interest in the design and use of collaboration scripts. There have also been some impressive efforts in improving the methodology of CSCL research, including through the use of new analytic and visualisation techniques. A rebalancing of emphasis from research that focuses on patterns of co-variation to research that tracks the sequence of critical events is particularly welcome, especially given the opportunities it opens up for explaining the processes behind observable patterns of variation and difference.

We have also identified a number of promising areas for future research. Some of these are being created by the richer flows of process data being generated by increasingly ubiquitous personal learning technology. Others are the result of a widening interest in

the spaces in which learning takes place – with distinct moves away from formal education and the classroom (virtual or otherwise).

The development of a range of applications, often subsumed under the broad heading of Web 2.0, opens up a new research area for CSCL. The new technologies suggest CSCL may need to operate at a different scale using large open networks in which participation is the structural imperative and ties between participants can vary in strength and nature. The study of the various media involved in Web 2.0 and the specific detail of how they might support CSCL is still in its infancy. CSCL will also need to understand the potential for collaboration in a technical landscape that invites users to blur the boundaries between a range of new and emerging applications on devices that are mobile and connected to fast networks. The study of large open networks is an emerging field for research both in terms of new ways to collect and visualise data but also in relation to the basic philosophy and understanding of what computer-support and collaborative learning might mean in this new context.

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