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Robert O. Briggs
University of Nebraska at Omaha, rbriggs@unomaha.edu

Gwendolyn Kolfschoten
Delft University of Technology, g.l.kolfschoten@tudelft.nl

Gert-Jan de Vreede
University of Nebraska at Omaha, gdevreede@usf.edu

Conan Albrecht
Brigham Young University - Utah, conan@warp.byu.edu

Douglas R. Dean
Brigham Young University - Utah, doug_dean@byu.edu

See next page for additional authors

Authors
Robert O. Briggs, Gwendolyn Kolfschoten, Gert-Jan de Vreede, Conan Albrecht, Douglas R. Dean, and Stephan Lukosch

A SEVEN-LAYER MODEL OF COLLABORATION: SEPARATION OF CONCERNS FOR DESIGNERS OF COLLABORATION SYSTEMS

Completed Research Paper

Robert O. Briggs
Center for Collaboration Science
University of Nebraska at Omaha
6001 Dodge Street, Omaha, NE 68135
rbriggs@unomaha.edu

Gwendolyn Kolfschoten
Delft University Technology
Jaffalaan 52628 BX, Delft
The Netherlands
g.l.kolfschoten@tudelft.nl

Gert-Jan de Vreede
Center for Collaboration Science
University of Nebraska at Omaha
6001 Dodge Street, Omaha, NE 68135
& Delft University of Technology
gdevreede@unomaha.edu

Conan Albrecht
Marriott School of Management
Brigham Young University
Provo, UT 84602,
conan@warp.byu.edu

Douglas R. Dean
Marriott School of Management
Brigham Young University
Provo, UT 84602,
doug_dean@byu.edu

Stephan Lukosch
Delft University Technology
Jaffalaan 52628 BX, Delft
The Netherlands
s.g.lukosch@tudelft.nl

Abstract

Designers of collaboration systems address many interrelated issues in a social-technical context. The volume, complexity, and variety of issues can invoke cognitive overload, causing deficiencies in system designs. We use inductive logic to derive seven key areas of concern for designers of collaboration support systems. We use deductive logic to argue that these areas address collaboration at differing levels of abstraction, and so may be organized into a seven-layer model, affording separation of concerns at design time. The layers are: Goals, Products, Activities, Patterns, Techniques, Tools, and Scripts. Design changes at one layer may not necessitate changes to layers above it, but may require changes to layers below it. At each layer and between each layer there are different issues and outcomes that may be addressed with different concepts, techniques and tools. This separation of concerns may reduce cognitive load for designers and may help to improve completeness and consistency of their designs, yielding higher productivity for collaborating groups.

Keywords: Collaboration, collaboration engineering, facilitation, collaborative work practice, collaboration technology, design methodologies.

Introduction

Groups collaborate to create value that their members cannot create through individual effort. Collaboration, however, engenders a set of interpersonal, social, political, cognitive, and technical challenges. Multiple actors with diverse backgrounds must establish common understandings (Weick, Sutcliffe, and Obstfeld 2005) and align their efforts (Ren, Kiesler, and Fussell 2008). They must think creatively, sometimes quickly, to solve problems (Rudolph, Morrison, and Carroll 2008) in the face of potential barriers (Ren, Kiesler, and Fussell 2008) and distractions (Laxmisan et al. 2007).

Research shows that, under certain conditions, groups can improve key outcomes using collaboration technologies. Any technology that can be used well, however, can also be used badly. IS/IT artifacts do not assure successful collaboration. The value of a collaboration technology can only be realized in the larger context of a *collaboration system,* which we define as a combination of actors, hardware, software, knowledge, and work practices to facilitate groups in achieving their goals, in an effective and efficient way.

Designers of collaboration systems must therefore consider social, psychological, cognitive, technical, and many other aspects of collaboration when creating a new collaboration system. Collaboration researchers across many disciplines have produced a substantial and growing body of exploratory, theoretical, experimental, and applied research that could inform design choices. Finding, assimilating, and using the concepts of collaboration science, however, can impose high cognitive load on designers, which in turn, can lead to design defects in collaboration systems. This, in turn, may result in lost productivity for system users. Designers of collaboration systems may therefore find it useful to have an organizing scheme for collaboration science that affords them a separation of concerns at design time. In this paper we derive a Seven-Layer Model of Collaboration (SLMC) to afford a multidimensional separation of concerns to collaboration system designers. We identify design considerations at the interface of each layer with the layer above it. We discuss the kinds of phenomena that manifest at each layer, the theories surrounding these phenomena, and approaches to measuring them. We argue that many collaboration technologies focus too narrowly on a few layers of the model. We argue that the next generation collaboration support systems should accommodate the mobilizing of understandings at all seven layers of the model. We also draw attention to caveats about the model as an organizing scheme.

Methods

We use inductive logic to derive the seven key areas of design concerns for collaboration systems. We gather the supporting evidence for our inductions from more than 400 collaboration science research papers in the Information Systems domain, and from several of its referent disciplines, among them Computer Science, Psychology, Management, and Education. We then use deductive logic to build an argument that these areas of concern address collaboration at differing levels of abstraction, and so may be organized into a seven-layer model, affording separation of concerns at design time. We validate the seven layer model by reporting on its use for to two different collaboration challenges in the field.

Seven Areas of Concern for Designers of Collaboration Systems

In this section we survey collaboration science literature of interest to the designers of collaboration systems. We synthesize this literature into seven key areas of concern. Table 1 summarizes those areas of concern.

Concerns Related to Goals

Many of the key concerns for successful collaboration relate to group goals, private goals, and the relationships among them. A *goal* is defined as a desired state or outcome (Locke and Latham 1990). Much research focuses on the role of goals in group formation (Hahn, Moon, and Zhang 2008), motivation (Vroom 1995), continuity (Lodewijkx, Rabbie, and Visser 2006), productivity (Wheelan 2009), and success (Levi 2007).

Key phenomena in collaboration science are defined in terms of group goals. Collaboration itself, for example, is defined as joint effort toward a group goal (Briggs et al. 2003). Definitions of the terms, *group* and *team,* often refer to the collection of people who have committed to work toward a group goal (e.g. Cohen and Bailey 1997). The effectiveness of a group is defined in terms of the degree to which a group attains the goals toward which it works

(Cohen and Bailey 1997). Group efficiency is defined in terms of the degree to which a group conserves its resources during the attainment of a group goal (Veld 1987).

Table 1. Seven Areas of Concern for Designers of Collaboration Systems

Area of Concern	Description
Goals	A *goal* is a desired state or outcome. Deals with group goals, private goals, and goal congruence – the degree to which individuals perceive that working toward group goals will be instrumental to attaining private goals. Collaboration is defined as joint effort toward a group goal. Addresses motivation, group formation, commitment, productivity, satisfaction, and other goal-related phenomena
Products	A *product* is a tangible or intangible artifact or outcome produced by the group's labor. Deals with issues of quality, creativity, effectiveness, efficiency, and other product-related phenomena.
Activities	*Activities* are sub-tasks that, when completed, yield the products that constitute attainment of the group goal. Deals with what groups must do to achieve their goals: sequences of steps that constitute decision-making and problem-solving approaches.
Patterns of Collaboration	*Patterns of collaboration* are observable regularities of behavior and outcome that emerge over time in teamwork. Researchers address six general patterns of collaboration: Generate Reduce, Clarify, Organize, Evaluate, and Build Commitment.
Techniques	A *collaboration technique* is a reusable procedure for invoking useful interactions among people working toward a group goal. Deals with invoking useful outcomes predictably and repeatably across a wide range of circumstances.
Tools	Collaboration *tools* are artifacts or apparatus used in performing an operation for moving a group toward its goals. Deals with designing, developing, deploying, and using technologies in support of group efforts.
Scripts	A *script* is everything team members say to each other and do with their tools to move toward the group goal. Scripts may be internal or external, tacit or explicitly captured as documentation. Deals with tacit and explicit procedural guidance for the group. Small variations in structured scripts can yield substantial variations in group dynamics. .

Other collaboration concerns pertain to the private goals of individual group members. Group cohesion is sometimes measured in terms of the degree to which an individual group member desires (has a goal) to remain a member of a group (Evans and Dion 1991). The Yield Shift Theory of satisfaction (Briggs, Reinig, and de Vreede 2008) predicts that individual team members will feel satisfied with their group to the extent that group processes and outcomes invoke shifts in the perceived utility of and likelihood of attaining private goals.

Other phenomena, such as motivation (Hayne 1999), commitment, consensus, and willingness to change, relate to *goal congruence* – the degree to which individuals perceive that working toward group goals would be instrumental toward attaining salient private goals. Instrumentality, Expectancy, and Reasons theories of motivation posit that motivation to make effort toward group goals will be a function of the degree to which individuals perceive value or benefit in the outcomes of the behaviors the group considers enacting (Westaby 2002). In a group setting, these perceptions pertain to the actions an individual contemplates toward helping a group attain its goals. The Instrumentality Theory of Consensus posits that individuals will only be willing to commit effort and resources toward a proposal for achieving a group goal to the extent that they perceive that outcomes of the effort would be

instrumental to their salient private goals (Briggs et al. 2005). The Value Frequency Model (VFM) for Change of Work Practice posits that an individual's willingness to change to a new way of working (e.g. a new collaborative approach) will be a function of the overall positive or negative value the individual perceives in using the new work practice, and the frequency with which the individual perceives that value will be attained (Briggs et al. 2007). VFM posits six dimensions of value: Economic, political, social, cognitive, affective, and physical. These dimensions pertain directly to the kinds of utility individuals anticipate from the attainment of their salient private goals.

Issues of group formation and cohesion, efficiency and effectiveness, satisfaction, consensus, willingness to change and other goal related phenomena must be addressed by the designers of designers of collaboration systems and -related phenomena. We generalize these concepts into an area of concerns labeled, "Goals."

Concerns Related to Products

Designers of collaboration systems must consider a number of aspects relating to the products a group will create through its joint efforts. Much research addresses group products. A *product* is a tangible object or intangible state produced by the group's labor, the existence of which advances a group toward its goal. The goal of an internal risk audit, for example, is to discover risks that have not yet been controlled or mitigated, and to develop controls to cover those risks. The product for an internal audit could be a list of risks organized by organizational unit, evaluated for likelihood and impact, elaborated with plans to mitigate each risk, and signed off by an auditor to signify that the controls are in place and functioning properly. The existence of this constitutes the attainment of the group goal for the risk assessment. Some products that groups create directly support attainment of formal group goals. Others are useful for instrumental goals. A brainstorm on project risks, for example, could lead to an idea for process improvements that does not only control risks, but also increases efficiency.

Meta analyses covering more than 300 studies (Baltes, Dickson, Sherman, Bauer, & LaGanke, 2002; Dennis & Wixom, 2002; Fjermestad & Hiltz, 1999; Hwang, 1998; McLeod, 1992) in the collaboration literature identify a number of issues pertaining to the products of collaboration as studied in the lab and the field. Some of these issues pertain to attributes of tangible products, e.g. quality of a decision (Kellermanns et al. 2008), and the quality, creativity, and number of solutions (Dean et al. 2006). Others pertain to intangible products like awareness of problems (Ravi Beegun and Leroy 2009), participation (Saltz et al. 2007), or gaining multiple perspectives (Clawson et al. 1993). Still others focus on the degree to which variations in the attributes of the team (Van Knippenberg and Schippers 2006), the task (Higgs, Plewnia, and Ploch 2005), and in other aspects affect the attributes of group products. We generalize these concepts into an area of concerns labeled, "Products."

Concerns Related to Activities

Collaboration systems designers focus much of their efforts on designing the sequence of activities through which a group moves to achieve its goals. *Activities* are sub-tasks that, when completed, yield the products that constitute attainment of the group goal. Activities reduce cognitive load by decomposing the group goal into manageable chunks, each with its own interim goals and interim products. Many researchers describe domain-specific models that decompose goal attainment into a series of generalized activities. Herbert Simon proposed an economic model for rational decision making based on the premise that people go through a series of activities when evaluating a decision (Simon, 1979). Management researchers decompose decision into variations on a set of activities typically including, problem identification, alternative generation, evaluation, and selection, planning, execution, and review (e.g. Schwenk 1984; Dean and Sharfman 1996; Mitroff et al. 1974). Psychology researchers also propose activities as a foundation for problem solving tactics. For example, D'zurilla and Goldfried (1971) defined problem solving as a behavioral process which includes problem definition and formulations, generation of alternatives, evaluation and selection, and verification of potential solutions. Variations on these activities can be found throughout many literatures. The logical design phase in systems analysis and design methodologies, for example, typically include activities for problem identification, alternative generation, evaluation, and choice (Whitten, Bentley, and Dittman 2007).

Collaboration technology researchers often discuss the capabilities of their systems in terms of the tasks or activities they support. Nunamaker, et. al. (1996) make frequent reference to the tasks and activities the users go through when using GSS software, among them idea generation, idea organization, and idea evaluation. Desanctis and Gallupe (1987) propose that GSS should support planning, creativity, intellective, preference, cognitive conflict, and mixed motive tasks. Using Speech-Act Theory, Flores and Winograd model collaboration processes as sequences of speech-act combinations to form standardized team activity workflows (Flores et al., 1988; Winograd and Flores

1986). Based on their modeling approach, various collaboration systems in the area of workflow management were proposed. From these related research streams we derive the area of concern we label "Activities".

Concerns about Patterns of Collaboration

Collaboration researchers have addressed a number of issues pertaining to how groups move through their activities. *Patterns of collaboration* are observable regularities of behavior and outcome that emerge over time in teamwork (Vreede et al, 2006). Collaboration engineering researchers identify identified six patterns of collaboration that characterize how groups move toward their goals (Vreede, et al, 2009).

- **Generate:** To move from having fewer concepts to having more concepts in the set of ideas shared by the group.
- **Reduce:** To move from having many concepts to a focus on fewer ideas deemed worthy of further attention.
- **Clarify:** To move from less to more shared understanding of the concepts in the set of ideas shared by the group.
- **Organize:** To move from less to more understanding of the relationships among concepts in the set of ideas shared by the group.
- **Evaluate:** To move from less to more understanding of the instrumentality of the concepts in the idea set shared by the group toward attaining group and private goals.
- **Build Commitment:** To move from fewer to more group members who are willing to commit to a proposal for moving the group toward attaining its goal(s).

Most of the behaviors in which a group engages as it moves through an activity can be characterized by these six patterns. In a risk assessment, for example, as a group moves through a risk identification activity, they may *generate* candidate risk statements, *evaluate* the likelihood and impact of each risk, and *reduce* the list to the risks that pose a credible threat to the organization.

Researchers study phenomena relating to each of the six patterns of collaboration. With respect to the *Generate* pattern, for example, studies report the number of ideas a group produces (Connolly et al. 1990), their originality, relevance, quality, effectiveness, feasibility, and thoroughness (Dean et al. 2006). People generate by creating new ideas (Reiter-Palmon et al. 1997), by gathering previously unshared ideas (Bock et al.), or by elaborating on existing ideas with additional details (de Vreede et al. 1999). For the *Reduce* pattern, researchers address, for example, the number of ideas in the shared set, the degree to which a reduced idea set includes high-quality ideas and excludes low-quality ideas (Barzilay et al. 1999), and the degree to which reduction of idea sets yields reductions of actual and perceived cognitive load (Simpson and Prusak 1995). Groups reduce idea sets through idea filtering (Chambless et al. 2005), generalizing ideas (Yeung et al. 1999) or selection (Rietzschel, Nijstad, and Stroebe 2006).

Researchers of the *Clarify* pattern focus on, among other things, reductions in ambiguity, reductions in the number of words required to convey meaning, and establishing mutual assumptions (Mulder, et al. 2002). Among the phenomena of interest for research on the *Organize* pattern of collaboration are shared understandings of the relationships among concepts (Cannon-Bowers and Converse 2001), cognitive load (Grisé and Gallupe 1999), and the simplicity or complexity of the relationships among concepts (e.g. complex structures may signify sequence, hierarchy, and networks of relationships, which in turn may model, for example, semantics of chronology, composition, heredity, or causation (Dean et al. 2000)). Research on the *Evaluate* pattern addresses projections of possible consequences of choices, and the degree to which those consequences would promote or inhibit goal attainment (Westaby, 2002). Rating, ranking, and inclusion/exclusion are common means of evaluation (Gavish & Gerdes, 1997). Research on such techniques focuses, for example, on the degree to which participants can accurately project the likely outcomes of the proposals they consider (Laukkanen, Annika Kangas, and Jyrki Kangas 2002). Phenomena of interest for the *Build Commitment* pattern pertain to the degree to which people are willing to contribute to the group's efforts (Montoya-Weiss, Massey, and Song 2001). Issues of commitment arise in many phases of group work, starting with the formation of the group (Datta 2007), and continuing through every proposed course of action and every choice group members make as they move through their activities (Saaty and Shang 2007).

From these streams of research, we induce an area of concern for designers of collaboration systems that we label, "Patterns of Collaboration"

Concerns Relating to Techniques

Researchers report many reusable collaboration techniques that groups can employ to improve group performance. A *collaboration technique* is a reusable procedure for invoking useful interactions among people working toward a group goal (Vreede et al. 2006). Consider, as an example, research on ideation techniques. Osborn (1963) proposed the brainstorming technique as a way to invoke synergy, and so to improve the number and quality of ideas produced by groups. Several subsequent studies reported that groups following Osborn's technique do not outperform those using nominal group technique (Diehl & Stroebe 1987). Losses from production blocking, free-riding (social loafing), and evaluation apprehension appeared to outweigh possible benefits from synergy (Collaros & Anderson, 1969; Diehl & Stroebe 1987). Groups using electronic brainstorming techniques however, were shown to outperform both manual and nominal teams (Connolly et al., 1990; Dennis et al., 1990; Fjermestad and Hiltz 1999; Gallupe et al. 1992).

Techniques that allow group members to interact anonymously appear to reduce evaluation apprehension (Connolly et al., 1990; Valacich et al., 1992) but may encourage social loafing (Harkins & Jackson, 1985; Paulus & Dzindolet, 1993; Sanna, 1992), but social comparison has been shown to reduce social loafing (Shepherd et al. 1996). Techniques that incorporate a devil's advocate role appear to foster creativity (Schulz-Hardt, et al. 2008) improve and idea quality (Schweiger et al. 1986), yet they may reduce collaboration process satisfaction (Schweiger et al. 1986; Valacich and Schwenk 1995). Techniques that decompose the problem space and/or solution space also appear to increase brainstorming performance (Dennis et al. 1997; Santanen et al. 2004). There are similar bodies of literature surrounding techniques for other patterns of collaboration, for team building, and for other aspects of collaboration. Research suggests that different techniques impose different level of cognitive load on group leaders and members (Kolfschoten et al. 2007; Kolfschoten et al. 2009), and different collaboration techniques may require different levels of facilitation and technology skills (Kolfschoten et al. 2009).

Researchers have begun to collect and codify collaboration techniques as design pattern languages for various aspects of collaboration (e.g. Aalst et al. 2003, Khazanchi and Zigurs 2006, Vreede et al. 2006). A design pattern *"describes a problem which occurs over and over again and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice"* (Alexander et al. 1977, p. x) Collaboration Engineering researchers have developed design patterns called thinkLets (Vreede et al. 2006; Kolfschoten et al. 2006; Vreede et al. 2009). ThinkLets are named, scripted collaboration technique for predictably and repeatedly invoking known patterns of collaboration among people working together toward a goal (Vreede et al. 2009). They enable rapid development of coherent, multi-layered collaboration processes that may improve the productivity and quality of work life for teams (Vreede et al. 2006). From the research on collaboration techniques and pattern languages, we generalize an area of concern we label "Techniques".

Concerns relating to Tools

A great deal of research has been done about the design (Reinig, Briggs, and Nunamaker 2007; Cataldo et al. 2006), deployment (Agres, de Vreede, and Briggs 2005), and use (Golder and Huberman 2006; Kamrani and Abouel Nasr 2008; Smith 2007) of tools to support collaboration. Collaboration *tools* are instruments or apparatus used in performing an operation for moving a group toward its goals, for example, whiteboards, flipcharts, or collaboration software systems. Collaboration tools must afford users with the capabilities they require to execute their work. The collaboration technology market is burgeoning with new products appearing monthly. A number of authors have proposed schemes for making sense of the range of capabilities offered in the collaboration space (Penichet et al. 2007; Bos et al. 2007; Mittleman et al. 2009; Sahni, Van den Bergh, and Coninx 2008). Researchers have developed and published a pattern language of design considerations for collaboration software. This work addresses ninety-seven generalized solutions for a range of functions such as community membership, workspace creation, shared artifacts, multi-modal communication, awareness, access control, persistence, and identification (Schummer and Lukosch 2007).

Researchers have produced hundreds of articles on the use of group support systems (GSS) to improve group productivity (see (Fjermestad and Hiltz 1998; Fjermestad and Hiltz 2000; Pervan and Arnott 2006) for thorough compendia of these works). These studies have addressed a broad set of topics such as anonymity (Valacich et al.

1992), group size (Gallupe et al. 1992), task type, task-technology fit (Zigurs and Buckland 1998), and national culture (Watson, Ho, and Raman 1994), (Desanctis and Gallupe 1987). Other researchers report on a variety of phenomena pertaining to, for example, wikis (Ebersbach et al. 2008), audio and video conferencing (Nguyen & Canny 2007), and metaverses (e.g. virtual worlds like Second Life) (Davis et al. 2009), reporting ways that collaboration technology use can improve or impede group performance. From this literature, we derive an area of concern we label, "Tools." We choose the term, "Tools" over the term "technologies" because we intend that both computer-based and non-computer-based tools be included in this area of concern.

Concerns Relating to Scripts

A number of studies in the collaboration science arena address the scripts people use to move a group toward its goal. A *script* is everything team members say to other and do with their tools to move toward the group goal. An unstructured script would be description of emergent actions and utterances. A structured script would provide team members with procedural guidance (I. Kollar, F. Fischer, and Slotta 2005), structuring and sequencing what participants in various roles should say and do to move the group forward. (Ingo Kollar, Frank Fischer, and Hesse 2006). Internal scripts are procedural knowledge embedded in the cognitive schema of individuals (Abelson 1981). External scripts are procedural guidance that is not necessarily integrated into the cognitive schemas of group members (Kollar, Fischer, and Slotta 2005).

Structured external scripts for a group are often derived from collaboration techniques. In the ThinkLets design pattern language, the essence of each technique is embodied as highly structured set of rules that specify a *sequence* of *actions* people in specific *roles* should take using certain *capabilities* under certain *constraints* (Kolfschoten et al. 2006). Each thinkLet includes a generic script that instantiates those rules. Designers of collaboration systems can tailor the thinkLet script or replace it completely, yet still invoke the same patterns of collaboration, so long as the new script still invokes the rules of the thinkLet (Kolfschoten et al. 2006).

Subtle variations in scripts can produce substantial variations in group performance. Simply instructing a brainstorming group to think creatively significantly increases the number of creative ideas they produce (Runco, Illies, and Reiter-Ralmon 2005). Instructing the group to engage in problem construction before brainstorming begins also increases their creativity (Reiter-Palmon et al. 1997). Shepherd, et al, (1996) reported that adding an invocation of social comparison to a brainstorming script increased the number of ideas produced by an anonymous brainstorming group by about 30% (e.g. "An average group produces about *xxx* ideas during a session like this. If you produce fewer, you are below average"). They found further that if the invocation were delivered in a jocular tone to increase its salience (e.g. "…If you produce less than that, you are brain-dead.)" productivity increased by another 30%. Other research showed that varying the order of 20 prompts covering five topics in a directed brainstorming technique could yield variations of as high as 300% in the number of creative ideas a group produced (Santanen, Briggs, and de Vreede 2000). Similar findings across a variety of domains demonstrate the value and importance of scripts to collaboration success. From this body of literature, we derive an area of concern that we label, "Scripts."

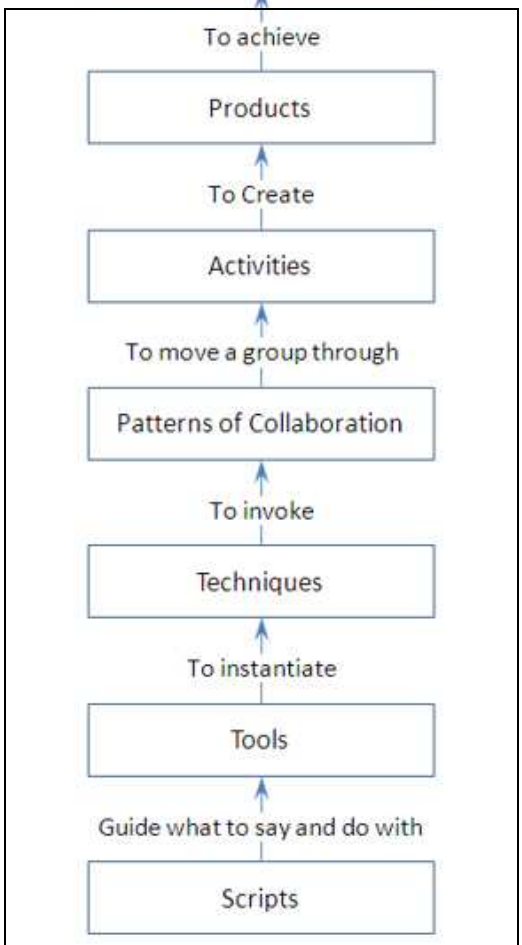

Figure 1. The Seven Layer Model of Collaboration. Each layer deals with collaboration different concerns for the designer of collaboration systems. Each has different phenomena of interest, and therefore different methods for modeling and measuring collaboration.

Deriving a Seven Layer Model of Collaboration

In this section we use deductive logic to argue that these areas of concern address collaboration at differing levels of abstraction, and so may be organized into a Seven Layer Model of Collaboration (SLMC), affording separation of concerns for designers of collaboration systems. Designers may make choices at every level that affect the layers below. Constraints at any level may affect the choices designers make at layers above. Figure 1 illustrates the layers of the model.

The Goals Layer

Without a group goal, collaboration does not exist. Unless the private goals of the individuals are congruent with the group goal, team members will not commit to collaborate, and so the group will not exist. If a group does not exist, then there is no need to address the other areas of concern. Concerns pertaining to goals must therefore comprise the top-most layer of the SLMC, because all other layers depend on the top layer.

The Products Layer

To achieve their goals, groups create products – artifacts and outcomes that constitute goal attainment. Until a group goal exists, one cannot assert the need for a product, nor judge the degree to which a product fulfills a goal. If a group changes its goals, it may need to change the products it will create because products are the means by which a group goal is realized. If a group creates a product that does not attain its formal or instrumental goals, that product has no purpose. Products therefore depend on goals. A group may decide to attain the same goal by creating different products. Goals are therefore independent of products. Concerns about products must therefore be subordinate to concerns about goals. Lacking a product, however, there would be no need to address concerns about activities, patterns of collaboration, techniques, tools, or scripts, because there would be no purpose to group action. The Products Layer must fall below the Goals Layer, but above the other layers in the SLMC.

The Activities Layer

Activities are sub-tasks for creating a group's products. Until there is a product to create, activities have no purpose. If a group changes the product it intends to create, it will have to change its activities, because activities produce sub-products leading to the products that attain the group goal. If the product changes, the sub-products must also change, so activities depend on products. A group may decide to use different activities to create the same product however, so products are independent of activities. Concerns about activities must therefore be subordinate to concerns about products. Lacking activities, however there would be no venue for realizing patterns of collaboration, techniques, tools, or scripts. The Activities Layer must therefore fall below the Products Layers, but above the Patterns of Collaboration, Techniques, Tools, and Scripts layers of the SLMC

The Patterns of Collaboration Layer

Patterns of collaboration characterize how a group moves through its activities. Until sub-tasks have been identified and their sub-products articulated, it would not be possible to determine what combination of patterns might be useful for create a sub-product. If a group changes the sub-products it intends to create, then it may need to change the patterns of collaboration it needs to create them, because the patterns must give rise to the sub-products. Concerns about Patterns of Collaboration must therefore be subordinate to concerns about activities. Patterns of Collaboration therefore depend on Activities. A group might decide to use a different combination of patterns of collaboration to create the same sub-products. Activities are therefore independent of patterns of collaboration. Lacking patterns of collaboration, it would not be possible to select among techniques because techniques are meant to invoke patterns of collaboration. Likewise, it would not be possible to select tools or create scripts. The Patterns of Collaboration Layer must therefore fall below the Activities layers, but above the Techniques, Tools, and Scripts layers of the SLMC.

The Techniques Layer

Techniques are used to invoke patterns of collaboration. Until patterns of collaboration have been selected, it would not be possible to select techniques to invoke them. Concerns about techniques are therefore subordinate to concerns about patterns of collaboration. If a group changes the patterns of collaboration it wants to use to move through its activities, then it will have to change the techniques it uses, because techniques invoke patterns of collaboration. Techniques are therefore dependent on patterns of collaboration. A group may choose to change the technique it uses to invoke a particular pattern of collaboration. Patterns of collaboration are therefore independent of techniques. Lacking techniques, it would not be possible to select tools for implementing a technique, because each technique requires specific capabilities, nor would it be possible to prepare a script describing how the technique is to be instantiated. The Techniques layer must therefore fall below the Patterns of Collaboration layer, but above the Tools and Scripts layers of the SLMC.

The Tools Layer

Tools afford the capabilities required to instantiate a collaboration technique. Until techniques have been selected, it would not be possible to select tools for instantiating the technique because each technique requires specific capabilities. Concerns about tools must therefore be subordinate to concerns about techniques. If a group changes the techniques it intends to use, it may need to change its tools, because the new techniques may require different capabilities. Tools are therefore dependent on techniques. A group may decide to use different tools to provide the capabilities their technique requires. Techniques are therefore independent of tools. Lacking tools, it would not be possible to create a script, because scripts provide guidance on how to use tools. The Tools layer must therefore fall below the Techniques layer, but above the Scripts layer in the SMLC.

The Scripts Layer

Scripts provide guidance about the things people in various roles should do and say with their tools to instantiate the techniques selected for the group. Until tools have been selected, it would not be possible to prepare a script describing how to use them. Concerns about scripts must therefore be subordinate to concerns about Tools. If a group changes the tools it uses, then it must change its script to describe how to use the new tools. Scripts therefore depend on tools. A group may decide to use a different way of describing how tools should be used. Tools are therefore independent of scripts. The Scripts layer must therefore fall below the Tools layer in the SMLC

Discussion

Concerns at the Interfaces between SLMC Layers

In addition to the concerns for each of the seven layers in the SLMC, there are concerns at the interfaces between each layer and the layer above it. Between the Products and Goals Layer, one must consider the degree to which products are valuable toward goal attainment. Because goals vary from group to group, there are no universal measures of product value; such measures must be derived on a task-by-task basis. It may be possible, however, to derive general measures of the *perceived* value of products, with questions like, "The outcomes of today's efforts will (advance / inhibit) the achievement of our goals." Likewise, between the Goals and Activities Layers, a designer must take into account the degree to which activities create products that serve group goals. The purpose of the six patterns of collaboration is to provide a logical understanding of how a group will move through the activities it must complete in order to create its products. Of interest between the Activities and Patterns layers, therefore, is the effectiveness and efficiency with which the designed sequence of collaboration patterns would move a group through its activities to their interim goals and products. The purpose of techniques is to invoke patterns of collaboration that will be useful for moving a group through its activities. Of concern at the interface between the Techniques and Patterns layers, therefore, would be the degree to which each technique invokes the requisite patterns. Between the Tools and Techniques layers, a designer must consider the degree to which a given technology affords required capabilities, and the degree to which those capabilities are afforded at a minimum of financial, political, social, cognitive, emotional, and physical cost. Of interest between the Tools and Scripts layer would be the degree to which the scripts lead the group to use their tools in ways that faithfully invoke the technique chosen by the work practice designer.

Implications of the SLMC for Designing and Deploying Collaborative Work Practices.

The seven layers of the SLMC offer a framework for the many design choices that one must make when planning collaborative efforts. Collaboration Engineering researchers have developed a structured approach to designing collaborative work practices (Kolfschoten and Vreede 2009) consisting of 6 phases to address these design choices. This approach addresses all seven layers of the SLMC. In the first phase the designer analyzes the task to understand the goals, deliverables and deliverables of the work practice, the stakes of the individuals who will execute the work practice and the resources available for the design effort. The next phase derives a set of activities for creating the deliverables. Based on this first blueprint of the process, the designer identifies patterns of collaboration for each activity and selects techniques (thinkLets) and the technologies to implement each activity. Having determined how the process will be executed, the designer adds further details, indicating the time frame for each activity and the information required for each activity (such as brainstorming questions or criteria for evaluation.) With this information the designer creates an agenda. Using this agenda, the process can be validated. In this step the relations between the layers are important, do the technologies afford the capabilities required for the techniques that should create the patterns of collaboration that move the group though activities to create deliverables that answer the goals of the group. Throughout the design effort, the process needs to be captured and documented in a more detailed prescription to make it transferable and reusable, addressing the final script layer.

Implications of the SLMC for the Next Generation of Collaboration Technologies

The current generation of collaboration technologies focuses almost exclusively at the Tools Layer of the SLMC. Users of collaboration technology, however, are not educated in the principles of collaboration science, and so may not know how to wield those tools to instantiate techniques to invoke the patterns of collaboration that will move them through their activities toward their goals. We propose that the next generation of collaboration technologies could present users not just with tools, but with well designed work practices. It should be possible for a collaboration system designer to configure purpose-built task-specific software applications to help a group articulate its goals, and to move through a series of activities to create the deliverables by which they will attain their goals. For each activity the system should present the group with just the tools they need, configured to support the techniques they will use to complete the activity efficiently. Those tools should link to the data sets the group needs for the activity, and should provide the communication channels the group will need to interact effectively. These systems should provide practitioners with scripts and other guidance that will let them move through the activities together. We propose that this generation of practice-centric technologies be called *Process Support Systems* (PSS). A PSS would present practitioners with a library of collaborative applications tailored to their specific high-value recurring tasks. Practitioners could select the application they needed, instantiate it as a virtual work space, and move as a group through the activities in the work practice.

A caveat

The Seven Layer Model of Collaboration conceives of collaboration as a *process* that may have economic, political, social, cognitive, physical, and technical dimensions. The model is, however, but one of many ways one could frame collaboration. It will also be valuable to explore collaboration from other perspectives - from a resource perspective; a behavioral perspective; as a value network, as a communication network, as a network of power and influence. These and other perspectives are also worthy of attention and effort.

Conclusions

This paper draws from literature in five academic disciplines using both inductive and deductive logic to derive the Seven Layer Model of Collaboration. It highlights key concerns for each layer, and discusses concerns that manifest between the layers. It discusses the realization of the seven layers in a methodology for designing collaboration systems. Because the model provides for a separation of concerns at design time, it may reduce the cognitive load of designers who must address a complex set of interrelated issues, which may, in turn, lead to better designs.

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