Temporal Considerations in Analyzing and Designing for Online Discussions in Education: Examining Duration, Sequence, Pace and Salience

Chapter 8 in *Assessment and Evaluation of Time Factors in Online Teaching and Learning*

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Abstract

Time plays a fundamental role in both the benefits and challenges of using online discussions as a pedagogical tool. This makes temporal considerations critical both for conducting analyses of how learning takes places through online discussions, and for designing effective structures to support discussion activity. However, despite the importance of temporal considerations for online discussions, the majority of research on online discussions and guidance for design does not explicitly address issues of time. This chapter provides an initial foundation for researchers, designers and instructors of online discussions to engage in temporally-aware analysis and design. We begin with an overview of the general temporal characteristics of online discussions and the analytic considerations they raise in terms of timescales, data aggregation and units of analysis. We then use the categories of Duration, Sequence, Pace and Salience as a framework for unpacking the temporal aspects of online discussions in more detail, providing guidance for designers and instructors to manage temporal challenges and harness temporal opportunities. We conclude with a call for greater theorization of temporal properties, processes, and their effects on learning to support more informed analysis and design of online discussions.

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Introduction

From their inception, online learning initiatives have navigated a space of tension between the opportunities technology provides for individualization of the learning experience and those it affords for facilitating interactions among learners. Supporting learning at "anytime and anyplace" while also enabling possibilities for collaboration and community-building is challenging indeed, especially when the former encourages diverse patterns of temporal engagement while the latter requires coordination across them. In this demanding context, asynchronous online discussions have emerged as an appealing way to couple learner independence with collaborative conversations. In other words, learners are able to engage in an educational experience both separately and together.

This bridging is possible partially because online discussions provide a communicative context with distinct, flexible temporal qualities (Hesse, Werner, & Altman, 1988). The core of all online discussions is the existence of a central message repository that persists over time. This allows learners to participate in a common conversation on their own schedule. It can also provide benefits not present in face-to-face discussions, such as extended time to reflect on others' commentaries, develop one's own and converse over a prolonged period of time (Harasim, 2000). However, the looser coupling of individual participation timelines can also cause pedagogical challenges; for example the problem of disjointed conversations in which learners don't meaningfully engage with one another's ideas is a well-reported phenomenon (e.g. Guzdial & Turns, 2000; Thomas, 2002).

Because the temporal characteristics of online discussions play a central role, in both their promise and peril, analyses that take such elements into account are critical for generating understanding of how learning does (and does not) take place through online discussions. Similarly, effective design of online discussions requires actively planning for the temporal aspects of discussion activity. Despite the importance of temporal considerations for online discussions, the majority of research on online discussions and the guidance for design does not explicitly address issues of time. This chapter takes a step towards remedying this situation by laying out key temporal characteristics of online discussions and presenting their implications for temporally-aware analysis and design. It is our hope that researchers, designers and instructors of online discussions reading this chapter will appreciate the need to consider time and generate ideas about it to inform their future work.

Theoretical Framing

Defining Online Discussions

Before diving into a discussion of how the characteristics of online discussions give rise to various temporal benefits and challenges, it is important to first clearly identify what these core characteristics are and describe how they delineate the boundaries of what is considered an online discussion for the purposes of this chapter. At a basic level, online discussions are a form of computer-mediated communication (CMC) which occurs among a group of people in an asynchronous fashion. Asynchrony refers to communication that occurs across "delayed time" (Christie & de Alberdi, 1985), in other words,

the acts of expressing and receiving a message do not need to occur at the same time. This functionally decouples individuals' timelines for communicative acts from each other (Jonassen & Kwon, 2001), allowing people greater control and flexibility in their activities, but also creating additional challenges for coordination among them.

Online discussions can be further differentiated from asynchronous communication media more generally through the use of a persistent message system: a dedicated virtual space which users can access and contribute to at any time. A shared persistent message system offers particular opportunities for supporting engagement over a prolonged period of time; for example, the ability to easily review an archive of the conversation. In this sense we consider the temporal aspects of online discussions as following in the tradition of "electronic bulletin boards"[1] (Preece, Maloney-Krichmar, & Abras, 2003). Finally, it is important to note that while current online discussion tools now offer the ability to include images, links, and audio- and video- clips as part of messages, the core functionality used in most tools is still text-based communication (Hew & Cheung, 2013); possible temporally-related reasons for this will be discussed later in the chapter. Online discussions, defined in this way, have become a common learning tool in higher education both in online courses and as a supplement to face-to-face instruction. Thus examining their temporal features and formulating strategies to support their effective use offers an important contribution to post-secondary pedagogy.

The Need to Consider Online Discussions Temporally

Time plays a fundamental role in both the benefits and challenges of online discussions as a pedagogical tool. At a basic level, the asynchronous format allows students to take as much time as they need to reflect on the contributions of others and compose their own thoughts in response (Harasim, 2000). This reduces the need for turn-taking (Shank & Cunningham, 1996) and means that students can work with ideas at their own speed, rather than rushing to comment on a topic before the group moves on (Prestera & Moller, 2001). As a result, students report spending increased time on discussions online, but also getting more out of them (Meyer, 2003). In addition, by prolonging and distributing the time period of engagement, online discussions provide particular opportunity for reflective participation (Poole, 2000). For example, one framework for thinking about knowledge-building in online discussions (Wise & Duffy, 2008) focuses on the spiral between the complementary processes of Externalization (collective online reflection) and Internalization (conscientious local practice) as learners iteratively bring their experiences from the world to the discussions and draw on the discussions to inform their practice in the world. Importantly, the model frames learning as an evolution of knowledge over a prolonged period of time with Externalization and Internalization occurring in a dynamic cycle.

At the same time that it provides these benefits, the asynchrony of online discussions also presents challenges to meaningful conversation. For example, students must make active efforts to repeatedly log-in to a discussion, waiting unknown and variable amounts of time for responses to their comments

[1] Listervs are another tradition sometimes included in the category of online discussions, but excluded here because their lack of a central persistent message repository leads to a different set of temporal considerations.

(Peters & Hewitt, 2010). Too much lag-time waiting for a reply can violate students' expectations and need for acknowledgement, potentially leading them to disengage and reducing the discussion's momentum (Dringus & Ellis, 2010). At the other end of the spectrum, a proliferation of posts can quickly become overwhelming (Peters & Hewitt, 2010), and unorganized threads with deep nesting make it difficult for students to follow the conversation or get a sense of it as a whole (Dringus & Ellis, 2005). This can result in many posts remaining unread, low or superficial levels of interaction between learners, and disjointed discussions that do not fulfill the purpose of a locus for meaning-making (Guzdial & Turns, 2000; Thomas, 2002).

Despite the fact that many of the proposed advantages and challenges of online discussions stem from the temporal nature of participation as described above, the majority of research conducted on how students interact and learn in online discussions has aggregated data over students and time. For example, common measures of involvement in discussions include the overall number of times all students access an online discussion, make posts, or open the posts of others (e.g. Hamann, Pollock, & Wilson, 2009; Palmer, Holt, & Bray, 2008), and a vast number of studies have used tallies of scores on different content analysis schemes to assess the quality of student contributions (e.g. see De Wever, Schellens, Valcke, & Van Keer, 2006; Hew, Cheung & Ng, 2010). While such studies can be useful in generating some understandings about online discussions (in particular providing easily calculable indices through which to compare discussions resulting from different instructional treatments), they do not directly examine the interactional processes through which group knowledge construction is achieved nor the individual trajectories through which individuals' understandings progress (Wise & Chiu, 2011; Jeong, 2003). Considering knowledge construction (and learning more generally) as a developmental phenomenon which occurs over time (Mercer, 2008), a large part of the picture of how learning through online discussions occurs remains unexplored.

There are several kinds of value that temporal analyses of online discussions can provide. In general, a better understanding of how groups and individuals construct knowledge offers the potential to better support such processes. Specifically, one important contribution of temporal analyses is that they can help unpack and explain the possible causes of differences found in group outcomes (Kapur, 2011). Another important reason to engage in temporal analysis is that it can expose important aspects of group and individual discussion experiences not revealed by aggregate statistics; in some cases this can substantially change the interpretation of a study's results (e.g. see Wise, Speer, Marbouti, & Hsiao, 2013). This raises question about the validity of work examining discussion processes which does not take time into account. Finally, a study of how group discussion processes flow over time can help to pinpoint the "pivotal moments" worthy of more in-depth follow-up examination (Suthers, Lund, Rosé, Dyke, Law, Teplovs et al., 2011). For these reasons, multiple scholars have argued for the need to develop temporal analyses to understand learning processes in asynchronous online discussions (Swan & Shea, 2005; Gibbs, Simpson, & Bernas, 2008) and collaborative learning more generally (Reimann, 2009; Kapur, 2011).

Approaches to Temporal Analysis of Online Discussion

In response to the calls described above, more researchers are conducting temporal analyses of group discussion processes, and to a more limited extent, of the personal processes of individuals engaged in discussions. Three major classes of approaches to analyzing online discussions over time have emerged: statistical, visualization-based, and microanalytic.

Starting with statistical methods, many studies take an event-centered approach (Reimann, 2009) in which online discussions are considered to consist of a discrete series of events (generally posts). Models can then be created to identify common and/or consequential sequences. One useful technique for identifying common sequences is lag sequential analysis (LSA), which identifies frequently occurring message pairs. For example in examining discussions among MBA students, Jeong (2003) showed that posts making arguments are more likely to be followed by posts contributing more arguments than ones evaluating the initial argument. Moving beyond visible actions, hidden markov modeling (HMM) can be used to infer common sequences among underlying states (represented as the probability of transition between them). The power of this approach was demonstrated by Soller & Lesgold (2007) in their examination of triads of students solving problems in a collaborative digital workspace. In this work, they trained a HMM based on sequences of students asking questions, expressing doubt and elaborating explanations via chat. The resulting five-state model predicted which student was the "knowledge sharer" in specific interaction sequences substantially better than a simple examination of which student contributed the most information. While HMM has not yet been applied extensively to model online discussion processes, it presents a promising avenue for future work.

Event-centered statistical approaches can also be used to identify consequential sequences. These are sequences that are influential in the discussion in some way, but may not occur routinely. For example, Halatchiyski, Oeberst, Bientzle, Bokhorst & van Aalst (2012) developed a technique called main path analysis that identifies the most important discussion trajectories (sequences of posts within threads) using the number of replies received as an indicator of value. Similarly, Jeong (2003) examined which discussion post sequence pairs (e.g. a disagreement followed by a disagreement) were most likely to lead to extended chains of responses and critical thinking events. Statistical discourse analysis (SDA; Chiu, 2008) is a technique that can identify both common and consequential posts sequences. For example, Wise & Chiu (2011) showed that after students in specific roles (synthesizer, wrapper) posted an extensive summary, the knowledge construction phase of students' posts in the subsequent time period was more advanced. This is a consequential sequence because it indicates a change in the discussion dynamic. In contrast, a common sequence found within the second time period was that posts which contained new ideas were significantly more likely to be followed by posts in basic phases of knowledge construction. Recent developments of SDA have also worked towards drawing connections between process and outcome measures, for example, entry condition variables predicted developmental event sequences (i.e. discussion processes), which, in turn, predicted learning outcomes (e.g. Molenaar & Chiu, in press).

A different class of techniques for looking at time using statistical methods draws on the long tradition of variable-centered research in education. These analyses can examine how particular characteristics of groups (or individuals) vary with respect to some index of time. For example, Muukkonen, Hakkarainen, Konsonen, Jalonen, Heikkil, Lonka, et al. (2007) used time series analysis to examine variation in student emotions related to schoolwork over a two-week period with data collected multiple times a day using mobile phones. Multivariate time series analyses can also be used to examine the relationships between the flux of different variables over time. In a different, mathematical modeling approach, Gottman (2003) used dynamic nonlinear modeling to examine how married couples' affect and degree of connection rise and fall during their arguments. While variable-centric methods may provide some useful insights in their application to analyzing online discussions, it also is important to note several challenges. These include the fragmented nature of the discussion processes (making it difficult to fulfill the assumption that the dependent variables traced are acted on continuously by the independent variable), data which is not generated at a regular (consistent) time-interval, and the limitations of variable-centric approaches to examine discussion processes that occur on different timescales in a unified way (Riemann, 2009).

A second class of approaches to temporal analysis relies heavily on the inspection of visualizations of online discussion activity. Much of this work creates a picture of how discussion "flows" over time, allowing for the examination of rhythms of discussion, peaks and valleys of intensity, and key moments of change in the patterns. For example, Haythornthwaite & Gruzd (2012) mapped out discussion activity over the duration of a semester chronologically and by the day of the week in order to identify an overall participation arc as well as cycles within it. Some work in this tradition develops visualizations based on specific theories of collaboration. For example, Dascalu, Rebedea, Trausan-Matu, & Armitt's (2011) work is based on the concept of polyphony, the notion of individuals acting independently yet coherently to achieve joint activity (as in a jazz band improvisation). Other work offers more generic temporal visualizations that can be combined productively with multiple conceptual frameworks. For example, Dyke, Kumar, Ai & Rosé (2012) have developed a sliding time window tool that allows researchers to look for changes in processes over time by varying the unit size (time window) used for analysis. Other work may not include time as an explicit axis in visualization, but uses it as part of a graph-theoretic approach to identify or weight linkages in networks among posts or people (e.g. Suthers, Dwyer, Medina, & Vatrapu, 2010; Goggins, Mascaro, & Valetto, 2013).

Finally, a third class of work engaging in temporal analysis of online discussions follows the tradition of in-depth microanalysis of computer-supported collaborative learning (Sawyer, 2006), examining discussion processes in detail as a related series of actions and interactions. Specifically the goal of this kind of analysis is not to develop generalized models or comprehensive visualizations but to carefully trace discrete trajectories of individual and group discussions activity over time (Stahl, Koschmann, & Suthers, 2006). Such "thick" description (Geertz, 1973) of temporal discussion processes generated from fine-grained analyses of discussion forum data both provides complementary insights to quantitative modeling and large-scale visualizations (Reiman, 2009) as well as an opportunity to establish the ground-truth of larger claims made (Wise, Speer et al., 2013). For example, Wise, Perera, Hsiao, Speer,

and Marbouti (2012), devised a microanalytic case study approach to construct a meaningful on-the-ground account of students' trajectories of participation in online discussions. These detailed narratives of students' behaviors and ideas have been used to both identify particular typologies of individual temporal behaviors (Wise, Hsiao, Marbouti, Speer, & Perera, 2012a) and trace the co-evolution of individual and collective ideas over time (Wise, Hsiao, Marbouti, & Zhao, 2012b).

Considering Timescales and Units of Analysis

When considering temporal processes in online discussions through any of these approaches, issues of timescale (Lemke, 2000) become very important to consider. The terms "macro" "meso" and "micro" are often used in literature to distinguish relatively larger-scale or fine-grained approaches; however the absolute time frames these terms refer to can vary greatly (e.g. compare Goodyear, 2006; Suthers et al., 2010; Wise, Perera et al., 2012). This may in part be due to differences in the meaning of each term in particular collaborative contexts (e.g. a useful "macro" timescale for a semester-long university class, week-long online discussion, and hour-long chat session may differ), but also differences in the concept of time to which the timescale refers. Specifically in temporal analyses there may be several different important conceptions of time at play: the timescale at which individual datum is generated, that over which data points accumulate, the (potentially aggregated) timescale for a meaningful unit of analysis, the time-window over which the analytic unit is usefully examined, and finally the whole-time over which the activity occurred.

For example to study the processes of group knowledge construction in online discussion among university students we might begin with the timescale over which a post is generated (generally minutes, though possibly seconds) and that over which multiple posts begin to accumulate (minutes, hours, days, even possibly weeks depending on the scope and intensity of discussion). A post itself could serve as the unit of analysis (for example considering the kind(s) of argumentation or knowledge construction contribution each makes; e.g., Jeong 2003; Wise & Chiu, 2011) or the unit of analysis could be taken as a series of related posts (for example those linked by a reply-relationship, or the uptake of an idea from one to another; e.g. Suthers et al., 2010). This unit might exist at the same timescale over which posts accumulate, or could potentially stretch longer (e.g. posts accumulate at the timescale of hours, but connections between them stretch across days or even weeks; Suthers & Medina, 2010). The third level is the time-window of aggregation. In some cases additional aggregation may not be needed and this timescale remains the same as that at which the posts were generated or accumulated; however to answer certain kinds of questions, an intermediate unit of aggregation can be useful. For example, compare what can be learned by studying the sequence in which different types of knowledge construction contributions appear in individual posts with an analysis that examines changes in the frequency of post characteristics across weeks of discussion (e.g. Wise & Chiu, 2011; Wise & Chiu, 2013). This is an important decision since the time-window of data aggregation can have a profound influence on the results of an analysis (Zeini, Göhnert, Krempel, & Hoppe, 2012). For this reason it is important to carefully choose an appropriate "resolution" for examining data with a given method, or alternatively to examine the results of different choices of data aggregation. It is also important to consider over what

time-window to consider the analytic unit; this may be the same or different than the whole-time over which the activity was conducted. For example, common posts sequences for a set of discussions that occurred over several months might be extracted collectively for the whole discussion series or separately for each discussion week; the former would highlight interaction patterns that were continuous across the whole activity while the latter would show how discussion processes changed over time.

Choices in defining each of these conceptions of time in a given research setting need to be informed by an understanding of both what timescales are theoretically meaningful in the learning context under study and which are functionally necessary to answer the research questions at hand. It is also important to consider whether the analysis will focus on the group-, individual- and/or idea-levels and if the same timescale and unit of analysis makes sense for each. Depending on the constructs under consideration, group, individual and idea trace timelines may be occur in parallel or nest inside each other. While such separation can be analytically useful, it is also important to attend to how group, individual and idea trace timelines emerge from and constrain each other. Thus, as work in this area progresses it is also critical to consider their interrelationships and develop ways to examine the connections between them (Stahl, 2013).

Exploring Key Temporal Dimensions of Online Discussions

Having overviewed the general temporal characteristics of online discussions and the analytic considerations they raise, we now inspect in more detail the various ways time plays a part in discussion processes. The following discussion draws on both theoretical propositions from the online discussion literature, and the small but growing body of empirical work examining time in online discussions. Throughout we identify areas in which further research is needed and draw out initial implications for temporally-aware online discussion design. To organize the discussion, we use a four dimension taxonomy (Hesse et al., 1988) as a framework for unpacking the temporal aspects of online discussions; thus we consider in turn duration, sequence, pace and salience. The notion of duration (also called scale) refers to the length of various events, and can also refer to the length of time-interval between them; sequence refers to the ordering and patterns of successive events, while pace relates to the rate at which events occur over time; finally salience refers to the degree to which temporality itself is "present" in the discussion (Hesse et al., 1988). Each of these categories may be considered for the activity of learners individually and that of the group collectively, as well as at micro- meso- and macro-timescales (however defined in a given discussion context). Finally each temporal concept can be considered both absolutely and in a relative sense; and each can be examined for constancy, regular change or irregular change over time (Dyke et al., 2012). In some cases it also useful to consider individuals' psychological experience of time as distinct from time measured objectively.

Duration

One of the core pedagogical benefits of online discussions highlighted in the literature is that the asynchronous interaction allows individual learners to take an unlimited amount of time to read and

reflect on the contributions of others and compose their own thoughts to share (Hesse et al., 1988; Harasim, 2000; Poole, 2000). This can be thought of as allowing individual control over the *duration* of their discussion participation activities. Released from a shared group timeline and the pressure to make a comment on a topic before the conversation has moved on, students can work with ideas at their own pace (Prestera & Moller, 2001), theoretically facilitating richer and more thoughtful comments (Veerman & Veldhuis-Diermanse, 2001). Indeed, research suggests that on average students spend more time on discussions online than possible in the classroom (Meyer, 2003), though there can be great variation across students. For example, Wise, Speer et al. (2013) found that undergraduate students using online discussions as part of a blended course clustered into three groups based on various factors such as the length of time spent on the discussions and average time spent viewing others' posts. Results indicated that about a third of learners were engaged only minimally in the discussions while almost half spent substantial, but concentrated time participating. The final twenty percent of students both engaged for substantial time and distributed this time more broadly across the discussion. While some work has begun to document benefits of an increased duration of time spent on making and reading posts on discussion quality (Wise, Zhao & Hausknecht, 2013a); more work is needed to understand how much time is "enough" (for different kinds of students in different contexts) and what uses of the extended available time are most valuable. Such information can be used to provide students with clear guidelines for productive participation and potentially encourage those devoting minimal time to discussions to do more.

In addition to allowing more thoughtful participation across the board, the ability to take an unlimited (and unseen) amount of time to compose and possibly edit one's thoughts before sharing them can encourage participation from individuals who might not choose to speak-up in a face-to-face classroom (Harasim, 2000). In this way, the dominance over time by those quick to compose their thoughts can be reduced (Hesse et al., 1998) allowing for more equitable contributions (Swan, 2002). However, while some studies report students' recognition of this benefit in their experiences with online discussions (Ellis, 2001), others document differences in participation related to factors such as cultural background and computer skills (Prinsen, Volman & Terwel, 2007). In addition, findings about improved equitability in participation patterns by men and women are still decidedly mixed (e.g. Yates, 2001; Gunn, McSporran, Macleod, & French, 2003). It is certainly possible that some power dynamics learned in face-to-face contexts can spill over into online environments. Also while the traditional tools of classroom discourse dominance are not available, others may be developed (e.g. posting excessively frequently or creating long posts that do not invite dialogue). For these reasons, more work is needed to understand what personal and design factors affect equitability in discussions and how it can better be promoted.

While the above-mentioned studies examined evidence of equitable participation based on posts contributed, in online discussions recipients of communication also have increased control over when (and if) they attend to the comments of others (Wise, Zhao et al., 2013a). In this way, the power of the overly verbose to command the duration to which their comments are attended, is reduced. However, this benefit depends on the use of a time-independent communication medium, the prime example of this being text. In contrast, both audio and video communication tools have more limited flexibility in

duration of both recording and playback, even when not used synchronously. In recent work comparing the use of text and audio-based asynchronous online discussions, Hew & Cheung (2013) found that despite the additional affordances audio messages provided, the majority of students in two case studies preferred text-based interaction. The number one reason cited for this choice was the additional time and ease to organize, review and revise their comments. This suggests a particular temporal advantage to text-based communication that may be worth preserving even as the availability of multimedia recording tools for online discussions increases.

Another duration-related benefit attributed to the asynchronous nature of online discussions is that they impose fewer constraints on learner personal schedules allowing for learning "anytime, anyplace." However, while learners indicate this flexibility and control as important to them (Ellis, 2001), it also raises challenges for their planning and time management (Allan, 2007) and brings up questions about how students interleave their discussion participation with the various other demands on their time. The concept of entrainment refers to the fitting of one timeline into another, generally less flexible, timeline (Tuan, 1977). In the early days of computing Sproull, Kiesler, & Zubrow (1984) found that students would willingly rearrange their lives to accommodate the restricted access time available to access computer labs. In contrast, the almost limitless flexibility afforded by current computing access reduces the priority it demands for entrainment, leading to learning that may end up happening in "no place at no time" (Jun, 2005). Thus while the ability for individual learners to control the duration of their participation activities and the time between these episodes is powerful, it also presents important challenges to address with learning design. One way instructors may address this challenge is by imposing some temporal requirements or structure on online discussion participation. In doing so, it is important that that there is a clear rationale for how constraining temporal flexibility will support discussion learning processes (Goodyear, 2006). For example, instructors can "bound" a discussion by putting temporal restrictions on a discussion's duration, creating a specific start and end for students to work within. This sets a frame for the discussion activity that can help students to focus their time, but still allows for flexible scheduling with it. Design strategies related to creating a temporal structure are discussed further in the pacing section below.

While asynchrony can present challenges for learners in managing their time, it also presents the opportunity for prolonged engagement. The existence of online discussions across delayed time (Christie & de Alberdi, 1985) makes it possible for a discussion to stretch over days, weeks and even months, generating a cycle in which learners come-to and step-away-from the discussion in succession. This can create virtuous circles between activity in the world and discussion about it (Wise & Duffy, 2008), or simply give time for ideas to germinate. In addition, the extended time within asynchronous discussion can support a group in slowly developing into a learning community (Waltonen-Moore, Stuart, Newton, Oswald, & Varonis, 2006). As learners are able to rethink and rework their ideas and reflect both on these and the ideas of others, greater opportunities for higher-order thinking can emerge (Meyer, 2003). One feature of online discussion that should support students in reviewing and reflecting on the discussion over time is the shared post archive; however such interactions have not been a major research focus. Encouragingly, initial evidence suggests that increased review of previously

read posts is related to greater levels of post responsiveness (Wise, Zhao et al., 2013a). Exploration of discussion design factors that encourage such behaviors (e.g. integrating reflective assignments with discussion work, assigning students particular discussion roles) and further examination of their effects seems like a promising area for future work.

A final important type of duration relevant in online discussions exists at the group level as the interval between a post and its response. Because of discussions' asynchronous nature, learners must wait an undetermined amount of time for a reply (Peters & Hewitt, 2010). When a learner's expectations for the duration of this lag and the actuality do not match, learners may become discouraged and disengage from a discussion, causing problems for the overall discussions momentum and vitality (Dringus & Ellis, 2010). Alternatively, learners may become preoccupied with checking for a response, rather than engaging with the discussion in a meaningful way (Wise, Perera, et al, 2012). Interestingly, Kalman, Ravid, Raban, & Rafaeli (2006) found that although the duration between responses is generally longer for online discussions than in synchronous communication environments, most replies still fall within an average response latency range particular to the discussion context. For example, Hewitt and Teplovs (1999) found that in online discussions among graduate level distance education students, posts had a high likelihood of getting a response within 24 hours, with the probability dropping after this point. Work is needed to better understand the different response duration patterns that occur in particular kinds of discussion contexts. As they are characterized, students will be better able to align their expectations with the likely interval, thus mitigating some of the above problems. In addition, student expectations for the interval to receive a response may need to be adjusted based on the kind of message they have posted. Working with graduate students engaged in a debate, Jeong (2004) found that critique messages received the overall highest rate of response (72%) but also had the longest lag time to receive a reply (1.04 days compared to .82 days for messages overall). Additionally, this work documented instances where threads remained active despite the presence of substantially long wait times. Given that quality responses to critiques may take increased time to formulate but are an integral part of discussion-based learning, this suggests that allowing enough time for such responses to occur and setting student expectations accordingly may be an important to support productive discussion-based learning.

Sequence

While the concept of duration provides a useful framework for thinking about individual timeline control, prolonged engagement, and latency expectation, it does not offer much purchase for investigating the relationships between discussion contributions. Given the strong theoretical foundations of online discussions in learning with and from others (e.g. see Lipponen, 2002; Stahl, 2004), such examination is critical to understanding how the processes of learning are achieved in this medium. We thus draw on the temporal concept of *sequence* to examine the ordering and patterns of successive events (Hesse et al., 1988). Note that the notion of sequence in online discussions has a different character than that of synchronous conversations in which comments are typically contributed linearly (aside from parallel conversations within a group). Specifically, the threaded nature of most online

discussions creates a branched post structure that must be accounted for in any analytic technique (Jeong, 2003; Wise & Chiu, 2011).

A group's temporal sequence in an online discussion can be thought of both linearly (e.g. the progression of a group's discussion from generating ideas to agreeing on a common stance; Gunawardena, Lowe, & Anderson 1997) and in terms of recurrent sequences (e.g. a competing claim is often followed by evidence; Lu, Chiu & Law, 2011). Each type of sequence (linear/ cyclical) can also be considered at multiple levels of granularity. At the smallest scale, the detailed sequencing and relationship between posts can be studied to understand how discussions unfold step-by-step, to diagnose problematic discussion dynamics, and to predict both subsequent discussion sequences and even learning outcomes (Jeong, 2003). For example, messages that appear earlier in a discussion can set the tone and focus for the group, whereas later attempts to steer the conversation may more easily be ignored (Pena-Schaff & Nicholls, 2004; Wise, et al 2012b). At a larger level of granularity, particular phases of the group's discussion can be considered (Wise & Chiu, 2011); again particular sequences of these phases may be more or less desirable and thus explain a group's success or provide an indicator that intervention is needed. Finally, at the broadest level, the sequencing of a series of discussion activities can be a useful concept to consider both in the design and analysis of learning trajectories over the course of a semester (De Wever, Van Keer, Schellens, & Valcke 2010). Importantly, regardless of the temporal frame used for considering sequence, it is important to remember that every discussion episode exists in the larger context of the group's and individuals' prior interactions. Thus examination of events beyond the current discussion processes under investigation can often aid in their interpretation (Suthers & Medina, 2010).

Starting at the smallest level of granularity, there are many frameworks for conceptualizing and analyzing online discussions which imply (or have the potential to imply) theoretical propositions about temporal sequences. However few address this issue directly. For example, many discussion analysis schemes posit particular qualities of posts as valuable, either classifying posts into different contribution types (e.g. question, reply, clarification etc.; Pena-Shaff & Nicholls, 2004) or evaluating each according to a series of common variables (e.g. existence of new ideas, degree of summarizing; De Wever, Schellens, Van Keer, & Valcke 2008; Wise, Saghafian & Padmanabhan, 2012). Despite clearly theorizing the value of the different kinds and qualities of contribution, the temporal relations between these that might be expected and/or desired are not often explicitly discussed. For example: Is it more productive for questions to be followed by clarifications, answers, or conflict? Do we expect a high degree of summarizing in one post to lead to a low probability of new ideas in the next? Being able to predict theoretically desirable (or undesirable) patterns is important methodologically because of the large number of possible sequences and thus the probability for Type I errors (Jeong, 2003). Thus a key element needed to support effective investigation of sequential process in online discussions is clearer temporal theorization.

To be precise and useful, such theorization may need to specify scope conditions, such as specific kinds of discussions. For example Jeong and colleagues have conducted multiple studies examining processes

of critical discourse in structured group debates in which learners are assigned to teams with positions to argue. Their work has shown that in this context critical discourse (indicated by the presence of disagreements) is most likely to occur when arguments to support or rebut positions are being exchanged, but that evaluation of arguments is often delayed till negotiation is underway (Jeong, 2003). Examining specific discussion design strategies to support argumentation, Brooks and Jeong (2006) found that segregating the discussion of supporting and opposing debate arguments across different threads led to more challenges of the arguments, while Jeong and Joung (2007) found that having students label their messages with pre-determined argumentation categories (e.g. "evidence," "explanation," "critique") reduced the frequency of challenges, and the frequency to which those challenges were responded. This work provides clear and specific implications for designing and facilitating discussions in a formal group debate setting; work remains to be done to see to what extent these findings apply to other discussion contexts, for example open class discussions or informal discussion forums.

At a larger level of granularity, a specific theoretical sequence of discussion phases is often more clearly implied; for example Garrison, Anderson, and Archer's (2001) community of inquiry framework considers cognitive presence through the successive phases of initiation, exploration, integration and resolution. However, questions of specification of temporal relationships between such phases still remain (Wise & Chiu, 2011). For example to what degree is it necessary for these phases to be strictly sequential versus merely successive (i.e. is it possible for a group to skip some phases, if so what does that imply?). Another question relates to whether the cycle is expected to be purely progressive or whether a group might productively return to the activities of a previously completed phase (e.g. after integration the group decides to explore more before moving to resolution). Finally, there a question of the importance of the coherence of the group in going through these phases (i.e. what happens if some individuals progress more quickly or slowly than others?) and whether the group's phases are considered to be temporally exclusive or if overlap can occur.

In some of the first empirical work examining phases of discussion activity, Wise and Chiu (2011) examined the flow of an online discussion with respect to Gunawardena, Lowe, & Anderson's (1997) model of knowledge construction. Using a combination of content analysis and statistical discourse analysis (Chiu, 2008), they systematically identified phases of discussion with dominant characteristics and probed the characteristics of "pivotal posts" that propelled the group from one phase to another. The results provided evidence supporting the progressive nature of the knowledge construction process (the discussion moved unidirectionally from basic phases to more advanced ones), but not the necessity of passing through each phase to reach subsequent ones (phases which involved dissonance were often skipped). Furthermore, the pivotal posts that transitioned groups to more advanced phases of knowledge construction were typically extensive summaries written in the middle of the discussion by students assigned to do so (via a Synthesizer or Wrapper role). This work provided an important contrast between theoretical and actual discussion processes and suggests a particular temporal intervention (assigning a summarization role in the middle of the discussion) to help elevate groups to advanced phases of knowledge construction.

Role assignment in general suggests a promising way to temporally structure discussion processes without over-constraining them (Dillenbourg, 2002), since roles operate at a moderate level of coercion. For example "starter" and "motivator" roles can be used to get a discussion rolling (Wise, Sagafian et al., 2012). However, there is a danger that if role assignments are rotated across students, those who have completed their role may feel less responsibility to the discussion and thus reduce their participation (Wise & Chiu, 2013). Encouragingly, research by De Wever et al. (2010) suggests that assigning roles to only some students for the first part of a discussion (or series of discussions) can support the group in collectively internalizing role responsibilities and advancing knowledge construction. Thus, the role intervention can be introduced initially and faded over time providing benefit to all students in a discussion group, even those without a role.

The concept of sequence can also be used to think about individuals' discussion activity. In this case instead of considering the ordering or pattern of how *posts* are contributed, the series of *actions* conducted by an individual as they both read the posts of others and create their own posts are considered (Wise, Perera et al., 2012). This introduces an even smaller level of temporal granularity than described above as these actions occur over the course of minutes and even seconds. For example, once logged-in to an online discussion, students may carefully read and re-read some series of others' comments before composing their own, or immediately write their post without attending to others' posts. While reading others' posts, they may attend to all the posts in chronological order, focus on a specific part of the discussion, or jump between disconnected posts across multiple threads. These series of actions present patterns that can be examined cyclically to identify common sequences (what is a student most likely to do immediately after logging in or right before making a post) and linearly to document consequential ones (what is the succession of read events that leads a student to make a particular post). Understanding these moment-to-moment behaviors of how learners' access others' posts in online discussions and the factors that influence this is critically important since for discussions to be truly interactive, they must involve not just contributing posts to the conversation but attending to the posts of others as well (Wise, Speer et al., 2012).

Initial work in this area using a temporal microanalytic case study approach (Wise Perera et al., 2012; Wise, Hsaio et al., 2012a) has shown that individual students engage in a wide range of behaviors during online discussions each time they log-in, through the course of a discussion activity, and across whole semesters of discussion-based work. To understand the influence of such behaviors on group interaction processes, research has been begun to track trajectories of participation and ideas across group and individual levels and examining how they interrelate over time (Wise, Hsiao et al., 2012b). Attempting to coordinate analyses across levels is challenging for several reasons including the differences in timescales described above and the fact that the discussion artifact available for analysis at the end of a discussion is not how participants experienced the living conversation at different points in time. The multi-level microanalytic approach (Wise, Hsiao et al., 2012b) has attempted to address these challenges and shed light on specific ways in which series of individual actions influence group processes and how group timelines and phases collectively set the stage for individual actions. Initial work is promising, showing both that individuals may "go silent" in an online discussion as a purposeful

discourse move while still continuing to read others posts, and that a disjointed discussion can make it possible for a student who has only skimmed part of the discussion to be uncontested when she presumes a group consensus around her ideas. However, this work has also identified challenges in collecting appropriate evidence to warrant inferences about how a group's (temporally distributed) patterns of engagement influence an individual's discrete actions. Thus, this is an area requiring further investigation before prescriptions for practice are drawn.

Pace

Building on the basic temporal notions of duration and sequence, *pace* refers to the rate at which events occur over time (Hesse et al., 1988); it thus invites consideration of the ideas of the density or dispersion of discussion activity. Variations in pace over the course of a discussion create a rhythm of conversation as groups engage (and withdraw) over time. With their asynchronous nature, online discussions are inherently capable of greater density of discussion in terms of the number of comments in a given period of time as the face-to-face limitations of turn-taking are no longer present (Shank & Cunningham, 1996). While this can provide benefits for student's individual expression of ideas and the presence of a multiplicity of views overall, it can also create pressure for students to keep up with rapidly proliferating discussions (Gabriel, 2004). Peters and Hewitt (2010) found that attempting to cope with discussion "overload" was a major challenge for graduate students enrolled in online courses and this led them to employ particular strategies in their discussion participation such as logging in frequently and skimming messages. This may be related to Wise, Hsaio et al.'s (2012a) finding that some students take a "coverage" approach to reading others' messages in online discussions. While this lets students ensure that they nominally look at all discussion posts, the attention to them is brief and superficial and thus the ideas are not built on or challenged in meaningful ways. For example, initial work suggests that the depth of responsiveness in students' posts is negatively related to the number of posts in the discussion (Wise, Zhao et al., 2013a). Another negative side effect of overly dense discussions is that students are less likely to notice flawed logic or inaccurate information in the conversation (Buller & Burgoon, 1996). Collectively this work suggests that managing discussion intensity through design factors such as group size and expected number of postings can be important in supporting discussions high in quality rather than quantity.

From the opposite perspective, one factor that can slow or lead to discontinuity in discussion pace is the length of comments made. As discussed earlier with respect to duration, online discussions create the possibility to share larger and better thought out ideas. However, without any dampening effects of non-verbal cues to yield the floor (Burgoon, Bonito, Ramirez, Dunbar, Kam, Fischer, 2006), the length of comments can balloon beyond what is useful. If students take the time to read and make sense of these comments, it may slow the pace of a discussion; however as described above, it is more likely that students will simply feel overwhelmed and skim or ignore them (Peters & Hewitt, 2010; Wise, Marbouti, Hsiao & Hausknecht, 2012). Deliberate avoidance of lengthy posts affects balance in discussion pacing as some threads stagnate while others proliferate rapidly; to the extent that longer posts contain important ideas, gaps in understanding or redundant discussion can occur. Of course very short posts

are also problematic since they tend to be shallow in their presentation of ideas (Dennen, 2001). At the post-secondary level, a guideline of several hundred words has been suggested as reasonable to allow for both thoughtfulness and interactivity (Wise, Zhao & Hausknecht, 2013b)

At the same time that high density discussion is possible, the flexibility to contribute over a prolonged period of time practically means that comments in online discussions are often quite temporally dispersed. Pacing of participation across a discussion or the term can vary based on interest in the topic as well as class and personal schedules. For example, Haythornthwaite and Gruzd (2012) examined posting patterns associated with graduate information science students' participation in a series of weekly reading-based discussions across eight iterations of an introductory distance learning class and found a strong cyclic rhythm of more frequent posts on weekdays than weekends. Gibbs et al. (2008) reports similar findings; however Poole (2000) found that Saturday was the busiest day for discussion in the graduate-level educational technology course she studied. Such differences may be due to the nature of the student population (e.g. full-time versus part-time) but also the temporal frame of discussion (e.g. in Poole's study discussions opened on Sunday and closed on Saturday). While research from face-to-face contexts indicates a high sensitivity of a group's interaction tempo to pending deadlines (Gersick, 1988), in an asynchronous context some learners may also strategically choose to front-load their participation (Gibbs et al. 2008). The latter pattern may actually be beneficial for promoting interactivity and critical discourse as research has consistently found that messages that are posted early in a discussion's life get more replies (Pena-Shaff & Nicholls, 2004) and challenges (Jeong & Frazier, 2008) than those posted later.

All this suggests that providing guidance to students about *when* to post within a discussion may be more useful in fostering critical dialogue than simple number of post requirements. Thus a consideration of different temporal factors expected to affect participation in a given context can help instructors to both anticipate and design for more effective periodicity in online discussions. For example, discussions are meant to be an interactive dialogue, so multiple rounds of posting are needed to respond to others' ideas, question and elaborate on the points made, and negotiate with others (Pena-Shaff & Nicholls, 2004). Thus instructors can require students to post on a number of different days (e.g. early, mid, and late-week) to encourage responsiveness and interactivity in a discussion. In addition, temporal guidelines can be linked to certain *kinds* of discussion contributions to support progress through phases of discussion (Jeong & Frazier, 2008). For example, in a problem solving discussion students could be encouraged to share possible solutions by a certain deadline and then move into a discussion of their relative merits. Finally, instructor feedback on discussion may also be more effective if timed appropriately; Zumbach & Reimann (2003) found that when feedback on interaction was presented to groups in the early stages it was more beneficial than later on.

Discussion pacing can also be examined in a linear sense across longer discussions or a series of discussions. For example, in addition to the weekly patterns described above, Haythornthwaite and Gruzd (2012) found a semester-long rhythm that resembled an arc; participation rose across weekly discussions from the start of class to mid-semester and then declined again towards the end. In contrast,

in examining the "wellness" of discussions without a specified duration (taking into account the density, intensity, latency, and response count of posts), Dringus and Ellis (2010) found that the vitality of discussions consistently dropped-off after a month. This suggests that for open-duration topics there may be a point when it is prudent to formally close a discussion. Instructors can use similar knowledge of the "endurance" of discussions in their context to choose appropriate timeframes for bounding conversations or monitor discussions in real-time with an eye towards identifying when a shift to a new discussion topic is needed.

From the student perspective, it may take some time to get used to the different pacing of an online discussion. Interestingly, while a group's collective rhythm arises from the articulation of individual participation patterns, it is still be experienced by each individual as an external phenomenon (Wise, Hsaio et al. ,2012b). As learners adjust to a new group's collective norms, they may be able to better align the rhythm of their activity with others (Hesse et al, 1988). To the extent that an individual's pacing is aligned with others in the group, there may be a stronger sense that interactivity expectations are being met; however this can still be challenged by individual differences in the subjective experience of pace (e.g. one person may feel a discussion is too sluggish while another finds it overwhelming). One particular challenge in online discussions is that when a discussion rhythm includes lulls in activity (periods of diminished pace), there can be a decay of individual and collective memory of the recent interactions. This creates a need for learners to re-situate themselves in the conversational context by re-reading prior messages or run the risk of contributing comments that are redundant or dissociated with the prior discussion (Hewitt, 2005). This is another situation in which integrating reflective activities with discussion participation could be valuable in structuring temporally-aware discussions.

As noted earlier, the power engendered by control of one's own timeline can raise challenges for planning and time management; compounding the problem is the fact that there is a lack of research-based guidance as to what kinds of individual discussion participation pacing is desirable for supporting learning. When thinking about pacing from an individual perspective, many of the benefits and concerns are similar to those described for individuals' control of their own duration of participation. Again, asynchrony breaks the constraint of a single timeline of engagement (generally controlled by an instructor) and allows for multiple timelines of engagement managed by the students themselves (Jonassen & Kwon, 2001). Thus students have a high degree of autonomy to not only determine for how long they engage with the discussion (duration) but also the timing of when and how often this occurs (pace). In particular the notion of pace allows us to examine whether students condense their participation in intense bursts or distribute it across time slow-but-steadily. Wise, Speer et al. (2013) suggested that in the face of many competing demands on their time, it may be preferable to have students engage in a smaller number of extended discussion participation sessions in which they can consider multiple ideas together instead of a larger number of sessions in which they read and reply to disconnected posts. It is proposed that this may lead to a slower, but more thoughtful, pace of discussion for the overall group; however, empirical research investigating this hypothesis is needed.

Salience

The notion of *salience* refers to the degree to which temporality is itself "present" in the discussion (Hesse et al., 1988). This can be considered both technically and psychologically. Technically, salience can be thought of as the degree to which an online discussion system makes the passage of time apparent or invisible. This is important since how an interface represents an online discussion can influence how learners interact with it (Swan, 2003; Teplovs, 2008). Psychologically, salience refers to the degree to which time is present in the minds of learners participating in the discussion (which is also influenced by the technical salience of the system) [Hesse et al., 1988]. This can be evidenced through a study of learners' discussion behaviors and by examination of comments that refer to past or anticipated future parts of the discussion.

Considering how the passage of time is represented in an online discussion, the great majority of online discussion forums in education use text-based interfaces (Hew & Cheung, 2013) that present posts in a threaded chronological list (Marbouti, 2012). While a time/date stamp is often used to indicate the absolute time at which the post was made, the visual representation of the posts only indicates the sequence in which they were made. This gives at least an initial (potentially false) impression of continuity and regularity in the conversation (Wise & Padmanabhan 2009). For example, learners can easily confound threads with high activity overall (even if greatly distributed over time) with those of high, but sporadic, intensity. Research suggests that such factors are important to learners in deciding with which parts of an online discussion they wish to engage (Wise, Marbouti et al., 2012). In addition, in representing a discussion as essentially a long list, learners may not be easily able to identify threads as coherent units which have temporal flow (Marbouti, 2012). As a result, what becomes salient is the *overall* sequence of posts presented in the discussion, leading students to often simply read and reply to the most recent contributions in a discussion (those at the bottom of the list) [Hewitt; 2005]. This can have various detrimental effects on discussion activity such as leading threads to die out prematurely (Hewitt, 2005). Thus the salience of particular aspects of time (e.g. accentuating the most recent contributions) may be something to be avoided from a pedagogical perspective.

On the other hand, visualizing certain aspects of the temporality of a conversation more faithfully (the recentness of contributions, the flow of different threads, areas of high intensity in interaction) could help learners more easily figure out how and where to usefully enter a conversation in progress (or one which they are coming back to). Marbouti (2012) has taken a first step in this direction with the creation of a graphical interface based on a hyperbolic tree structure. His interface presents discussions as "starbursts" where branching threads grow radically from a central originating post. Thus time is visualized as proceeding outwards and the sequential flow of posts within a thread is more salient. Initial research on this interface suggests that it encourages students to read (and re-read) higher level posts prior to newer ones, thus supporting more cohesive discussion participation (Marbouti, 2012). Thus, in a sense the technical salience of time in the tool can be seen to promote a psychological salience of time for learners. However, while this interface makes the temporal sequence of posts more salient, it still displays posts spaced at even intervals, and thus does not effectively visualize the duration between

posts or pace of discussion. Wise and Padmanabhan (2009) have experimented with visualizations to address this problem and developed a scaled response tree format that makes the relative timing of the threads, the flow within a thread and intense discussion episodes apparent. The diagram has been used to analyze discussions post-hoc but it remains to be seen if a useful live interface can be created from this model.

Finally, another approach to increase the salience of time for students connects to the emerging field of learning analytics and rapidly improving capabilities to provide students with data on their discussion participation using extracted traces of their digital activity. In initial work, Wise et al. (2013b) have developed a series of temporally-related metrics including as the number and span of days a student logs-in to a discussion, the average length of time they spend when they log-in, and the degree to which the re-visit posts they have made or viewed previously. These metrics are used as part of an integrated learning analytics intervention in which students are given initial guidelines about the purpose of engaging in the discussions and characteristics of productive engagement (e.g. students are ask to distribute their posts both early and late in the week to support an interactive dialogue in which people build on each other's' ideas) and then periodically provided with data helping them to evaluate if they are meeting the criteria. By making the temporal aspects of individual participation visible to students, they can become more aware of them as an element of their engagement with the discussions.

Conclusion

This chapter reviewed the core temporal characteristics of online discussions through the categories of duration, sequence, pace and salience, and explored their implications for temporally-aware analysis and design. Consideration of duration in online discussions invites attention to the opportunities and challenges provided by prolonged engagement, the time learners spend on particular kinds of discussion activities, and the gaps in time between these actions. Based on the existing research, initial guidelines for managing duration in online discussions have been presented; however, further work is needed to determine with greater specificity which durations (for a discussion overall, for different phases within a discussion, and for particular discussion activities) are most effective for particular discussion contexts and purposes. The notion of discussion pace builds on duration to allow examination of how discussion activity is condensed or dispersed over time, the rhythms of individual and group activity, and how they interrelate with each other. Strategies for managing groups' discussion intensity, individuals' expectations, their alignment with group rhythms, and the use of guidelines and reflective activity to support resituation in an ongoing discussion are ways in which instructors can take pace into account in discussion design and facilitation. The notion of salience also presents possibilities for supporting more effective temporal discussion processes by strategically highlighting or obscuring the passage of time. The design of discussion forum tools and the use of associated learning analytics are two promising avenues for work in this direction. Finally, the concept of sequence in online discussions goes to the heart of the interaction between learners in a discussion. It can be used to look at the ordered relationships between posts, discussion phases, and even multiple discussions to identify both common and consequential patterns. Sequential analyses can also be applied to study the behaviors of individuals

interacting in a discussion, and how activity at the individual and group levels interrelates over time. Challenges in studying discussion sequences include determining both the grain size and analytic technique most useful for answering different kinds of research questions.

In conclusion, we wish to draw attention to what is perhaps the current biggest challenge for temporal research of online discussions: the lack of clearly articulated theorization about time. While time has long been considered a source of benefits and challenges for online discussions, theorization of temporal properties, processes, and their effects on learning has not generally been specified at a level of precision that has allowed for empirical testing. The urgent need for greater theorization in this area is heightened by the recent development of a variety of temporal methodologies presented in this chapter that make such testing realizable. Greater attention to the complementary work of both theorizing and empirically investigating temporal discussion processes has much to offer our understanding of how learning through discussions is accomplished. In turn, such work offers the potential to better guide instructors, designers and students in how to manage the temporal challenges that online discussions present and how to harness the temporal opportunities they provide.

References

Allan, B. (2007). Time to learn? E-learners' experiences of time in virtual learning communities. *Management Learning, 38*(5), 557-572.

Brooks, D. & Jeong, A. (2006). The effects of pre-structuring discussion threads on group interaction and group performance in computer-supported collaborative argumentation. *Distance Education*, *27*(3), 371-390.

Buller, D. B., & Burgoon, J. K. (1996). Interpersonal deception theory. *Communication Theory, 6*(3), 243–267.

Burgoon, J. K., Bonito, J. A., Ramirez, A., Dunbar, N. E., Kam, K., & Fischer, J. (2006). Testing the interactivity principle: Effects of mediation, propinquity, and verbal and nonverbal modalities in interpersonal interaction. *Journal of Communication*, *52*(3), 657-677.

Chiu, M. M. (2008). Flowing toward correct contributions during groups' mathematics problem solving: A statistical discourse analysis. Journal of the Learning Sciences, 17(3), 415–463.

Chiu, M. M., & Khoo, L. (2005). A new method for analyzing sequential processes: Dynamic multi-level analysis. *Small Group Research, 36,* 600-631.

Christie, B., & de Alberdi, M. (1985). Electronic meetings. In B. Christie (Ed.), *Human factors of information technology in the office* (pp. 97-144). Chichester, England: Wiley & Sons.

Dascalu, M., Rebedea, T., Trausan-Matu, S.,& Armitt, G. (2011). PolyCAFe: Collaboration and utterance assessment for online CSCL conversations. In H. Spada, G. Stahl, N. Miyake & N. Law (Eds.) *Proceedings*

of the 2011 International Conference on Computer Supported Collaborative Learning (pp. 781-785). Hong Kong: International Society of the Learning Sciences.

De Wever, B., Schellens, T., Valcke, M., & Van Keer, H. (2006). Content analysis schemes to analyze transcripts of online asynchronous discussion groups: A review. *Computers & Education, 46*(1), 6–28.

De Wever, B., Schellens, T., Van Keer, H., & Valcke, M. (2008). Structuring asynchronous discussion groups by introducing roles: Do students act up to the assigned roles? *Small Group Research, 39(6)*, 770–794.

De Wever, B., Van Keer, H., Schellens, T., & Valcke, M. (2010). Roles as structuring tool in online discussion groups: The differential impact of different roles on social knowledge construction. *Computers in Human Behavior, 26*(4) 516-523.

Dennen, V.P. (2001). *The design and facilitation of asynchronous discussion activities in web-based courses: Implications for instructional design theory*. Unpublished doctoral dissertation. Bloomington, IN: Indiana University.

Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. In Kirschner, P. (ed.) *Three worlds of CSCL: Can we support CSCL?* (pp. 61-91). Heerlen, The Netherlands: Open University of the Netherlands.

Dringus, L. P., & Ellis, T. (2005). Using data mining as a strategy for assessing asynchronous discussion forums. *Computers & Education*, *45*(1), 141–160.

Dringus, L. P., & Ellis, T. (2010). Temporal transitions in participation flow in an asynchronous discussion forum. *Computers & Education, 54*(2), 340-349.

Dyke, G., Kumar, R., Ai, H., Rosé, C. P. (2012). Challenging Assumptions: using sliding window visualizations to reveal time-based irregularities in CSCL processes. In J. van Aalst, K. Thompson, M. Jacobson, & P. Reimann (Eds.) *The future of learning: Proceedings of the 10th International Conference of the Learning Sciences* (pp. 363-370). Sydney, Australia: International Society of the Learning Sciences.

Ellis, A. (2001). Student-centred collaborative learning via face-to-face and asynchronous online communication: What's the difference? In *Proceedings of the 18th ASCILITE Conference*, Melbourne (pp. 9-12).

Gabriel, M. A. (2004). Learning together: Exploring group interactions online. *Journal of Distance Education, 19*(1), 54–72.

Garrison, D. R., Anderson, T., & Archer, W. (2001). Critical thinking, cognitive presence, and computer conferencing in distance education. *American Journal of Distance Education*, *15*(1), 7-23.

Geertz, C. (1973). Thick description: Toward an interpretive theory of culture. In C. Jenks (Ed.) C*ulture: Critical concepts in sociology, Vol 1* (pp. 173-196). New York: Routledge.

Gersick, C. J. G. (1988). Time and transition in work teams: Toward a new model of group development. *Academy of Management Journal, 31*(1), 9-41.

Gibbs, W., Simpson, L. D., & Bernas, R. S. (2008). An analysis of temporal norms in online discussions. *International Journal of Instructional Media, 35*(1), 63–75.

Gilbert, P., & Dabbagh, N. (2005). How to structure online discussions for meaningful discourse: A case study. *British Journal of Educational Technology, 36*(1), 5-18.

Goggins, S. P., Mascaro, C. & Valetto, G. (2013). Group informatics: A methodological approach and ontology for sociotechnical group research. *Journal of the American Society for Information Science and Technology.* Advanced online publication. DOI: 10.1002/asi.22802

Goodyear, P. (2006). Technology and the articulation of vocational and academic interests: Reflections on time, space and e-learning. *Studies in Continuing Education, 28*(2), 83-98.

Gottman, J. (2003). *The mathematics of marriage*. Cambridge, MA: MIT Press.

Gunawardena, C. N., Lowe, C. A., & Anderson, T. (1997). Analysis of a global online debate and the development of an interaction analysis model for examining social construction of knowledge in computer conferencing. *Journal of Educational Computing Research, 17*(4), 397–431.

Gunn, C., McSporran, M., Macleod, H., & French, S. (2003). Dominant or different? Gender issues in computer supported learning. *Journal of Asynchronous Learning Networks, 7*(1), 14–30.

Guzdial, M., & Turns, J. (2000). Effective discussion through a computer-mediated anchored forum. *Journal of the Learning Sciences, 9*(4), 437- 469.

Halatchliyski, I., Oeberst, A., Bientzle, M., Bokhorst, F., & van Aalst, J. (2012). Unraveling idea development in discourse trajectories. In J. van Aalst, K. Thompson, M. Jacobson, & P. Reimann (Eds.), *The future of learning: Proceedings of the 10th International Conference of the Learning Sciences* (pp. 162-166). Sydney, NSW, Australia: International Society of the Learning Science.

Hamann, K., Pollock, P. H., & Wilson, B. M. (2009). Learning from “listening” to peers in online political science classes. *Journal of Political Science Education, 5*(1), 1-11.

Harasim, L. (2000). Shift happens: Online education as a new paradigm in learning. *The Internet and Higher Education, 3*(1), 41-61.Haythornthwaite, C., & Gruzd, A. (2012). Exploring patterns and configurations in networked learning texts. *in System Science (HICSS), 2012 45th Hawaii International Conference on* (pp. 3358-3367). IEEE.

Hesse, B.W., Werner, C.M., Altman, I. (1988). Temporal aspects of computer-mediated communication. *Computers in Human Behavior, 4*(2), 147–165.

Hew, K. F., & Cheung, W. S. (2013). Audio-based versus text-based asynchronous online discussion: Two case studies. *Instructional Science, 41*(2), 365-380.

Hew, K. F., Cheung, W. S., & Ng, C. S. L. (2010). Student contribution in asynchronous online discussion: A review of the research and empirical exploration. *Instructional Science*, *38*(6), 571-606.

Hewitt, J. (2005). Toward an understanding of how threads die in asynchronous computer conferences. *Journal of the Learning Sciences, 14*(4), 567-589.

Hewitt, J., & Teplovs, C. (1999). An analysis of growth patterns in computer conferencing threads. In C. M. Hoadley & J. Roschelle (Eds.) *Proceedings of the International Conference on Computer Supported Collaborative Learning 1999* (pp. 232-241). Stanford, CA: International Society of the Learning Sciences.

Jeong, A. C. (2003). The sequential analysis of group interaction and critical thinking in online threaded discussions. *American Journal of Distance Education, 17*(1), 25-43.

Jeong, A. C. (2004). The combined effects of response time and message content on growth patterns of discussion threads in computer-supported collaborative argumentation. *Journal of Distance Education, 19*(1), 36-53.

Jeong, A. C., & Frazier, S. (2008). How day of posting affects level of critical discourse in asynchronous discussions and computer-supported collaborative argumentation. *British Journal of Educational Technology, 39*(5), 875-887.

Jeong, A. C., & Joung, S. (2007). Scaffolding collaborative argumentation in asynchronous discussions with message constraints and message labels. *Computers & Education*, *48*(3), 427-445.

Jonassen, D. H., & Kwon, H. (2001). Communication patterns in computer mediated versus face-to-face group problem solving. *Educational Technology Research and Development, 49*(1), 35-51.

Jun, J. (2005). Understanding e-dropout. *International Journal on E-Learning, 4*(2), 229-240.

Kalman, Y. M., Ravid, G., Raban, D. R., & Rafaeli, S. (2006). Pauses and response latencies: A chronemic analysis of asynchronous CMC. *Journal of Computer-Mediated Communication*, *12*(1), 1-23.

Kapur, M. (2011) Temporality matters: Advancing a method for analyzing problem-solving processes in a computer-supported collaborative environment. *International Journal for Computer-Supported Collaborative Learning, 6*(1), 39-56.

Lemke, J. L. (2000). Across the scales of time: Artifacts, activities, and meanings in ecosocial systems. *Mind, Culture, and Activity, 7*(4), 273-290.

Lipponen, L. (2002). Exploring foundations for computer-supported collaborative learning. In Stahl, G. (Ed.) *Proceedings of the International Conference on Computer Supported Collaborative Learning 2002* (pp. 72–81). Boulder, CO: International Society of the Learning Sciences.

Lu, J., Chiu, M. M., & Law, N. (2011). Collaborative argumentation and justifications: A statistical discourse analysis of online discussions, *Computers in Human Behavior, 27*(2), 946-955.

Marbouti, F. (2012). Design, implementation and testing of a visual discussion forum to address new post bias. *Masters thesis, Simon Fraser University*.

Mercer, N. (2008). The seeds of time: Why classroom dialogue needs a temporal analysis. *Journal of the Learning Sciences, 17*(1), 33–59

Meyer, K. (2003). Face-to-face versus threaded discussions: The role of time and higher-order thinking. *Journal of Asynchronous Learning Networks, 7*(3), 55-65.

Molenaar, I., & Chiu, M. M. (in press). Unraveling sequential and temporal relations between cognition and social regulation during collaborative learning. *Metacognition and Learning.*

Muukkonen, H., Hakkarainen, K., Konsonen, K., Jalonen, S., Heikkil, A., Lonka, K., et al. (2007). Process- and context-sensitive research on academic knowledge practices: Developing CASS-tools and methods. In C. Chinn, G. Erkens & S. Puntambekar (Eds.), *Proceedings of the 6th International Conference on Computer-supported Collaborative Learning (CSCL 2007)* (pp. 541–543). New Brunswick: International Society of the Learning Sciences.

Palmer, S., Holt, D., & Bray, S. (2008). Does the discussion help? The impact of a formally assessed online discussion on final student results. *British Journal of Educational Technology, 39*(5), 847-858.

Pena-Shaff, J. B., & Nicholls, C. (2004). Analyzing student interactions and meaning construction in computer bulletin board discussions. *Computers & Education*, *42*(3), 243-265.

Peters, V. L., & Hewitt, J. (2010). An investigation of student practices in asynchronous computer conferencing courses. *Computers & Education, 54*(4), 951-961.

Poole, D. M. (2000). Student participation in a discussion-oriented online course: A case study. *Journal of Research on Computing in Education*, *33*(2), 162-77.

Preece, J., Maloney-Krichmar, D., & Abras, C. (2003). History of emergence of online communities. In B. Wellman (Ed.), *Encyclopedia of community.* Berkshire Publishing Group, Sage, 1-11.

Prestera, G. E., & Moller, L. A. (2001). Exploiting opportunities for knowledge-building in asynchronous distance learning environments. *Quarterly Review of Distance Education, 2*(2), 93-104.

Prinsen, F., Volman, M. L. L., & Terwel, J. (2007). The influence of learner characteristics on degree and type of participation in a CSCL environment. *British Journal of Educational Technology, 38*(6), 1037–1055.

Reimann, P. (2009). Time is precious: Variable- and event-centred approaches to process analysis in CSCL research. *International Journal for Computer-Supported Collaborative Learning*, *4*(3), 239-257.

Sawyer, R. K. (2006). Analyzing collaborative discourse. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 187-204). Cambridge: Cambridge University Press.

Shank, G., & Cunningham, D. (1996). Mediated phosphor dots: Toward a post-cartesian model of CMC via the semiotic superhighway. In C. Ess (Ed.), *Philosophical perspectives on computer-mediated communication* (pp. 27-41). Albany, NY: State University of New York Press.

Soller, A., & Lesgold, A. (2007). Modeling the process of collaborative learning. In U. Hoppe, H. Ogata & A. Soller (Eds.) *The role of technology in CSCL: Studies in technology enhanced collaborative learning* (pp 63-86). New York: Springer.

Sproull, L.S., Kiesler, S., & Zubrow, D. (1984). Encountering an alien culture. *Journal of Social Issues, 40*(3), 31-48.

Stahl, G. (2004). Building collaborative knowing. In P. W. Strijbos, P. A. Kirschner, & R. L. Martens (Eds.), *What we know about CSCL and implementing it in higher education* (pp. 53–85). Dordrecht, Netherlands: Kluwer Academic Publishing.

Stahl, G. (2013). Learning across levels. *International Journal of Computer-Supported Collaborative Learning. 8*(1), 1-12.

Stahl, G., Koschmann, T., & Suthers, D. D. (2006). Computer-supported collaborative learning: An historical perspective. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 409–426). Cambridge: Cambridge University Press.

Suthers, D. D., Dwyer, N., Medina, R., & Vatrapu, R. (2010). A framework for conceptualizing, representing, and analyzing distributed interaction. *International Journal of Computer-Supported Collaborative Learning, 5*(1), 5-42.

Suthers, D. D., Lund, K., Rosé, C., Dyke, G., Law, N., Teplovs, C., et al. (2011). Towards productive multivocality in the analysis of collaborative learning. In H. Spada, G. Stahl, N. Miyake, N. Law & K. M. Cheng (Eds.), *Proceedings of the 9th International Conference on Computer-Supported Collaborative Learning (CSCL 2011)* (pp. 1015-1022). Hong Kong: International Society of the Learning Sciences.

Suthers, D. D., & Medina, R. (2010). The temporal development of representational practices: Implications for theory and analysis of situated learning, *Hawaii International Conference on the System*

Sciences (HICSS-43). Kauai, Hawaii. (CD-Rom). New Brunswick: Institute of Electrical and Electronics Engineers, Inc. IEEE.

Swan, K. (2002). Building learning communities in online courses: The importance of interaction. *Education, Communication & Information, 2*(1), 23-49.

Swan, K. (2003). Learning effectiveness: what the research tells us. *In J. Bourne & J. C. Moore (Eds) Elements of Quality Online Education, Practice and Direction.* Needham, MA: Sloan Center for Online Education, 13-45.

Swan, K & Shea, P. (2005). The development of virtual learning communities. In. S. R. Hiltz & R. Goldman, (Eds.) *Asynchronous learning networks: The research frontier* (pp. 239-260). New York: Hampton Press.

Teplovs, C. (2008). *The Knowledge Space Visualizer: A tool for visualizing online discourse.* Paper presented at the Common Framework for CSCL Interaction Analysis Workshop at the International Conference of the Learning Sciences. Utrecht, NL.

Thomas, M. J. W. (2002). Learning within incoherent structures: The space of online discussion forums. *Journal of Computer Assisted Learning, 18*(3), 351-366.

Tuan, Y. (1977). *Space and place: The perspective of experience*. Minneapolis: University of Minnesota Press.

Veerman, A., & Veldhuis-Diermanse, E. (2001). Collaborative learning through computer-mediated communication in academic education. In P. Dillenbourg, A. Eurelings, & K. Hakkarainen (Eds.), *Euro CSCL 2001* (pp. 625-632). Maastricht, Netherlands: Maastricht University.

Waltonen-Moore, S., Stuart, D., Newton, E., Oswald, R., & Varonis, E. (2006). From virtual strangers to a cohesive learning community: The evolution of online group development in a professional development course. *Journal of Technology and Teacher Education*, *14*(2), 287-311.

Wise, A. F., & Chiu, M. M. (2011). Analyzing temporal patterns of knowledge construction in a role-based online discussion. *International Journal of Computer-Supported Collaborative Learning*. *6*(3), 445-470.

Wise, A. F., & Chiu, M. M. (2013). *The effects of summarizing roles on learner's listening behaviors in online discussions.* Paper presented at 2013 Annual Meeting of the American Educational Research Association, San Francisco, CA.

Wise, A. F., & Duffy, T. M. (2008). Designing online conversations to engage local practice: Implications of a knowledge-building framework. In R. Luppicini (Ed.) *The handbook of conversation design for instructional application*s (pp. 177-202). Hershey, Pennsylvania: Idea Group Incorporated.

Wise, A .F., Hsiao, Y. T., Marbouti, F., Speer, J. & Perera, N. (2012a). Initial validation of "listening" behavior typologies for online discussions using microanalytic case studies. In J. van Aalst, K. Thompson, M. Jacobson, & P. Reimann (Eds.) *The future of learning: Proceedings of the 10th International Conference of the Learning Sciences* (pp. 56-63). Sydney, Australia: International Society of the Learning Sciences.

Wise, A. F., Hsiao, Y. T., Marbouti, F., & Zhao, Y. (2012b). Tracing ideas and participation in an asynchronous online discussion across individual and group levels over time. In J. van Aalst, K. Thompson, M. Jacobson & P. Reimann (Eds.) *Proceedings of the 10th International Conference of the Learning Sciences* (pp. 431-435). Sydney, Australia: International Society of the Learning Sciences.

Wise, A. F., Marbouti, F., Hsiao, Y. T., & Hausknecht, S. (2012). A survey of factors contributing to learners'" listening" behaviors in asynchronous online discussions. *Journal of Educational Computing Research*, *47*(4), 461-480.

Wise, A. F., & Padmanabhan, P. (2009). Developing structural-temporal visualizations of asynchronous threaded online learning conversations. In T. Bastiaens et al. (Eds.), *Proceedings of the E-Learn Conference 2009—World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education* (pp. 3253-3261). Vancouver, BC: AACE.

Wise, A. F., Perera, N., Hsiao, Y., Speer, J., & Marbouti, F. (2012). Microanalytic case studies of individual participation patterns in an asynchronous online discussion in an undergraduate blended course. *Internet and Higher Education, 15(*2), 108–117.

Wise, A. F., Saghafian, M., & Padmanabhan, P. (2012). Towards more precise design guidance: Specifying and testing the functions of assigned student roles in online discussions. *Educational Technology Research and Development, 60*(1), 55-82

Wise, A. F., Speer, J., Marbouti, F., & Hsiao, Y. (2013). Broadening the notion of participation in online discussions: Examining patterns in learners' online listening behaviors. *Instructional Science, 41* (2), 323-343.

Wise, A. F., Zhao; Y., & Hausknecht, S. N. (2013a). *Connecting students' listening and speaking behaviors in asynchronous online discussions.* Paper presented at 2013 Annual Meeting of the American Educational Research Association, San Francisco, CA.

Wise, A. F., Zhao; Y., & Hausknecht, S. N. (2013b). Learning analytics for online discussions: A pedagogical model for intervention with embedded and extracted analytics. In D. Suthers & K. Verbert (Eds.) *Proceedings of the 3rd International Conference on Learning Analytics and Knowledge*. Leuven, Belgium: ACM.

Yates, S. J. (2001). Gender, language and CMC for education. *Learning and Instruction, 11*(1), 21–34.

Zeini, S., Göhnert T., Krempel L., & Hoppe H. U. (2012). The impact of measurement time on subgroup detection in online communities. In *Proceedings of the 2012 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining*, (pp. 389-394), Instanbul, Turkey: IEEE.

Zumbach, J., & Reimann, P. (2003). Influence of feedback on distributed problem based learning. In B. Wasson, S. Ludvigsen, and H.-U. Hoppe (Eds.), *Designing for change in networked learning environments* (pp. 219-228). Dordrecht: Kluwer.

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Definition of Key Terms

Online Discussion: A form of asynchronous computer-mediated communication among a group of people that uses a persistent message system.

Asynchronous: Communication mode in which participants do not need to be present at the same time.

Duration: The temporal length of events or the interval between them.

Sequence: The ordering and patterns of successive events.

Pace: The rate at which events occur over time.

Salience (of Time): The degree to which temporality itself is "present" in a discussion.

Grain Size: The time scale over which data points need to be aggregated to create a meaningful unit of analysis.

Time Window: The span of time over which an analytic unit can be usefully examined (this may be the whole-time of the learning activity or some smaller portion of it).