Basic Principles of Interaction for Learning in Web-Based Environment

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Abstract

To teach in a web-based environment, what should the new instructor know about online interaction? This paper first reviews four instruments that examined the processes and outcomes of interaction (the foci are more on the interaction behaviors) and three instruments that examined interaction from a structural view (the foci are more on the interaction patterns). This paper then continues with the discussion on how to involve interaction theories in web-based learning. The author intends to explore the questions: What tools are currently available to facilitate the design and delivery of interaction in online learning? What factors have shown salient influences on group interaction? And how can the educators, instructional designers, and researchers utilize those research results? The purpose of the paper is to present the variety of options and the basic principles for designing and implementing interaction for new online instructors.

*Key words***:** Interaction, interaction theory, web-based learning, online learning, online teaching, distance education

Introduction

Interaction is one of the most discussed topics and is considered as a key variable in distance education by many educators (Anderson, 2003b; Bernard, Abrami, Borokhovski, Wade, Tamim, Surkes et al., 2009; Daniel & Marquis, 1979; Fahy, 2001b; Moore, 1989; Sims, 1999; Simonson, Smaldino, Albright, & Zvacek, 2009; Sutton, 2001; Wagner, 1994 & 1997). Psychologists have long believed that individual cognitive skills are developed in a social context and that there is a clear link between critical thinking, social interaction and deep learning (Newman, Webb, & Cochrane, 1995). According to Vygotsky's social development theory (n.d., as in TIP: The Theories), social interaction plays a fundamental role in the development of cognition. People must learn between people first, before they can learn inside themselves and allow the knowledge to become internalized. Habermas' (1984, as cited in Garrison, 1992) theory of communicative action indicated that meaning emerges

interactively. Garrison (1992) argued that individuals create meaning through communicative action, not in isolation. These theories all provided strong philosophical support for the importance of interaction.

Many studies have been done and many tools have been developed to answer the important questions regarding online interaction, such as how learners interact with each other; how learners co-construct knowledge through interaction; how to examine effects of different types of interaction; how to assess the levels of interaction that the learning groups have evolved; etc. This paper intends to explore the questions: What tools are currently available to facilitate the design and delivery of interaction in online learning? What factors have shown salient influences on group interaction? And how can the educators, instructional designers, and researchers utilize those research results?

To address the analysis aspects for understanding the educational quality of online learning interaction, this paper describes seven frequently referenced models to present the various angles that previous studies took in analyzing online interaction. Other factors that were considered being influential to online interaction by previous researchers are also described.

Previous Studies

Previous researchers have developed various models and tools to facilitate the interaction analysis. These instruments provided the basis to "guide and interpret practice in a wide range of context" (Garrison, 1992).

Definition

"Definitions are never true or false; they are only more or less useful" (Eisenberg & Goodall, 1993). Wagner (1994) defined interactions as "reciprocal events that require at least two objects and two actions. Interactions occur when these objects and events mutually influence one another" (p. 8). She argued that the purpose of an instructional interaction is to "respond to the learner in a way intended to change his or her behavior toward an educational goal" (p. 8). This definition is suitable

for the discussion of the interaction supported by contemporary technologies and to the distance education context (Anderson, 2003b).

Gunawardena, Lowe, and Anderson (1997) defined interaction as "the totality of interconnected and mutually-responsive messages" (p. 407). For studies that used transcript analysis as the key method, this definition suited them well (Fahy, 2001b).

Interactivity.

Interactivity is a term often confused with interaction. Interactivity refers to the ability of the medium which allows the user to respond to or gain feedback from the technology, while interaction is a learning behavior (Gunawardena, 1999). In computer science, interactivity is a term often used to describe the interaction opportunities that technology provides to its users, such as the controls of the sequence, the pace, and what to look at and what to ignore (Sims, 1999). Although in many distance education writings, interactivity was not distinguished from the term interaction (Anderson, 2003b), this paper excludes interactivity in the scope of the discussion. However, this paper does cover a non-human form of interaction: the learner-content interaction.

Types of interaction

Moore (1989) argued that it is necessary for the important term, interact, to have a generally agreed definition and specific sub-meanings so that the communication of its concepts could be precise and avoid problematic misunderstanding. Moore described three types of interaction in distance education: learner-content interaction, learner-instructor interaction, and learner-learner interaction. The "content" in the first type of interaction included many kinds of media such as print, broadcast, audio, video and computer software. Moore's three types of interaction have been widely used in the discussion of the field. Based on his definition, interaction, in a broad sense, covered almost all active processes that constitute teaching and learning.

Hillman, Willis, and Gunawardena (1994) argued that Moore's discussion of interaction was inadequate. They proposed a learner-interface interaction to address the interaction between learner and the electronic classroom.

Sutton (2001) further presented the fifth type of interaction – the vicarious interaction. Sutton argued that although some learners did not directly interact with peers, they learned from observing and processing interactions between others.

Anderson (2003a) rejected the proposition of the fourth and the fifth types of interaction. He argued that all forms of interaction in distance education context are mediated forms of interaction. Therefore, learner-interface interaction was a component of each of the other interactions whenever they occur in a distance education context and should not be considered as a unique form of interaction. As for vicarious interaction, it could only occur in combination with other forms of interaction. Without the active interaction of other participants, it could not be realized. Therefore, vicarious interaction is a variant of all forms of interaction, not a distinct form of interaction.

Anderson (2003a) proposed another three types of interaction: teacher-teacher interaction (interaction between and among teachers), teacher-content interaction (the development and application of content objects), and content-content interaction (intelligent programs or agents). Since reports regarding these three new types of interaction and vicarious interaction were not commonly found, these interactions are beyond the scope of this paper.

In the next two sections, this paper describes two groups of interaction studies. The studies in the first group examined the outcomes and processes of interaction; and the studies in the other group examined the structure of the interaction network.

Outcomes and Processes of Interaction

A large portion of interaction studies fell into the first category. These studies investigated the outcomes and processes of interaction. Main questions which this group of studies tried to answer were: what kind of thinking was stimulated in the learners; and to what extent was the interaction

appropriate for the task at hand (Bates, 1990). These studies examined the types and the processes of cognitive activity performed; the types of arguments advanced; the resources brought in by participants for use in exploring their differences and negotiating new meanings; and the evidence of changes (Gunawardena, 1999).

Henri's five dimensions.

Henri (1991, as cited in Newman, Webb, & Cochrane, 1995) provided five dimensions for analyzing the quality of computer-mediated communication (CMC): social dimension, interactive dimension, cognitive dimension, and meta-cognitive dimension, as well as a quasi-quantitative participative dimension. Henri's model has been widely cited but also has been criticized for its teacher-centered approach and vagueness in distinction between dimensions (Gunawardena et al., 1997; Newman et al., 1995). Henri's model has provided good stimuli to many later scholars in the process of developing various tools for understanding online interaction. (Gunawardena et al., 1997, & Newman et al., 1995)

Critical thinking model and cognitive presence from Garrison.

Helping learners to be able to conduct critical thinking has been one of the utmost purposes of education; therefore, the discussion on learning interaction has often been linked up with the discussion of critical thinking. Garrison (1991) proposed a five-stage model that integrated critical thinking and reflective learning. The stages are: problem identification, problem definition, problem exploration, problem evaluation/applicability, and problem integration. The model corresponded closely to the cognitive skills in Henri's model and the five phases in Brookfield's model (Garrison, 1992). In 2000, the five-stage model was developed into the cognitive presence in the influential Community of Inquiry model. The five stages were changed into four stages: triggering event, exploration, integration, and resolution (Garrison, Anderson, & Archer, 2000). The revised model considered not only the cognitive processes of participants but also the action for facilitating effective group online interaction.

Interaction Analysis model from Gunawardena et al.

In searching for a proper interaction analysis model for a global online debate, Gunawardena, Lowe, and Anderson (1997) developed the Interaction Analysis (IA) Model for Examining Social Construction of Knowledge in Computer Conferencing, after reviewing the strengths and shortcomings of existing interaction analysis methods including models from Henri, Levin et al., and Garrison. They developed this IA model to accommodate the large group and no strong facilitator presence settings of the Global Online Debate (Garrison, Anderson, & Archer, 2000). IA model contained five phases: Sharing/Comparing, Dissonance, Negotiation/Co-construction, Testing Tentative Constructions, and Statement/Application of Newly-Constructed Knowledge. They argued that interaction was the process through which the participants negotiated their meaning and co-created the knowledge. Each phase of the process was like a quilt block that formed the entire gestalt of the textile craft. The coding result of that global debate using the IA model was not very satisfactory. Gunawardena et al. (1997) reported that 90% of the respondents' postings were coded into one area that was the first or the second Phase (p.427). While re-examining the validity and the discriminant capability of the instrument, the researchers concluded that informal professional discourse was not congruent with the active construction of new knowledge.

Table 1

Comparison chart of Henri's, Garrison's, and Gunawardena's models

No.	Henri's (dimension)	Garrison's (stage)	Gunawadena's (phase)
1	Social dimension	Elementary clarification	Sharing/Comparing
2	Interactive dimension	In-depth clarification	Dissonance
3	Cognitive dimension	Inference	Negotiation / Co-construction
4	Meta-cognitive dimension	Judgment	Testing tentative construction
5	Participative dimension	Strategy formation	Statement / Application of newly-constructed knowledge

Interaction process analysis from Bales.

In discussing group interaction, the abundant studies done by social psychologists should not be ignored. Robert F. Bales' Interaction Process Analysis (IPA) is one of the most influential and durable systems for examining face-to-face small group interaction (Burke, 2005; Fahy, 2004 & 2005). The IPA is a set of twelve complementary-paired categories classified under four categories: positive reaction, negative reaction, attempted answers/suggestions and attempted questions, the former two are classified as social emotions while the latter two are task areas (Bales, 1950 & 1951) (See Appendix A). Its ability to identify the presence of both task and relational functions in group interaction has been proved to be valid by many studies. However, its requirement of one single code for one statement has caused difficulty in data coding because statements in discussion were often subtle and complex (Fahy, 2005). Fahy (2004 & 2005) made modifications on this coding requirement and applied it to two studies. His experience showed that the IPA, a tool for analyzing face-to-face interaction, was capable of categorizing and explaining important aspects of online group communications, activities, and behaviours.

Structure of Interaction Network

Different from the qualitative approach taken by the above mentioned studies, another category of studies added a quantitative lens to the methods in understanding of web-based learning interaction. With the support of computer technology, the researchers inspected the structure and the pattern that described the levels and spread of "what is happening" in web-based learning using mathematical formula and interpret-friendly graphs. Furthermore, they tried to prescribe "what it would be" using simulative what-if scenario, mathematically manipulatable key variables, based on a theoretical framework. The researchers believed that using objective measures to analyze the structure of the group interaction was an approach that could increase the interrater reliability and reduce the subjective interpretation. As a consequence, the exchange flow and the directedness of web-based learning interaction would be revealed more clearly (Fahy, 2001b).

The key methods used in this group of studies were derived from or influenced by a multidisciplinary method - social network analysis. Social network analysis aims to identify, measure, and test hypotheses about the structural forms and the substantive contents of relations among actors. One of the major assumptions is: structural relations, e.g., density, centrality, and cohesiveness are often more important for understanding observed behaviors than are individualistic variables, e.g., age, gender, and grade (Knoke & Yang, 2008). Basic tools for representing network data are graphs and matrices that facilitate sophisticated mathematical and computer analyses of network data (Knoke & Yang, 2008).

Message Maps from Levin et al.

Levin, Kim, and Riel (1990) proposed a method - Message Maps (See Appendix B), which display the interrelationships among the messages submitted by participants, and answered the question about who's interested in which topic, and when. Although the Message Map helped to illustrate the multi thread nature of electronic message interaction, when all the messages sent during a period of time were put in a single Message Map, the map would be quite complicated, and difficult to read (See Appendix C).

Transcript Analysis Tools from Fahy.

Transcript analysis has been criticized for its poor reliability and the discriminant capability of identifying major characteristics in a particular setting (Fahy, 2001a). To address these two major problems, Fahy developed the Transcript Analysis Tool (TAT) that contains two parts. One is the five types of sentences (questions, statements, reflections, engaging comments, and quotations/citations) that corresponding to different modes of interaction. By calculating the number of each type of sentences, educators could learn in what ways the participants engaged in the interactional processes. Another is a set of structural elements (network size, density, and intensity) suggested by social network theory (See Appendix D).

Since the sentence types were easy to distinguish and the calculation of the density and intensity (see Appendix E) was simple, TAT demonstrated a moderate to good level in inter-rater reliability in several case studies (Fahy, 2001b, 2002, 2003, 2005). When compared to the discriminant capability of previous studies, TAT appeared to be able to detect and describe the interactive behavior and network patterns of an online community from broader angles than other models (Fahy, 2001a). However, how to interpret rich meanings by reading the mathematical results requires insightful judgment.

Epistemic Network Analysis from Shaffer et al.

Tools for understanding interaction have met new challenges since the web-based learning environment become more dynamic and education focused more on performance in context than in paper and pen. One apparently unsolved question is how to assess the ongoing interactions that takes place in immersive models of distance education such as multi-user virtual environment (MUVE) and epistemic games. Shaffer, Hatfield, Svarovsky, Nash et al. (2009) have developed an Epistemic Network Analysis method to assess the performances in a fast changing digital learning environment that came with a click-through interface. The stealth embedded assessment occurred during the learning processes when the learners make decisions or take actions by clicking on the interface. The clicks were automatically recorded by the computer and the records were coded using predefined frame elements (Frame elements are similar to the categories and the indicators used in content analysis); then assembled into the network graphs (See Appendix F). Finally, the educators studied the forms of interaction network graphs and the codes to see if there were key interactions that made significant contributions to learners' development of epistemic frames and how the internal thoughts of individuals changed over time. Since the graphs represented the interactive behaviors of participants, educators could examine the processes of the group interactions or the interaction strategies of the individuals. ENA model represented an emerging new approach for assessing interaction.

Other Factors That Influence Group Interaction

Interaction and group size.

Group size was discussed in interaction studies because of two main reasons: group size increases the potential complexity of the network (Fahy, 2001b); and there is a cognitive limit to the number of relationships that individuals are able to maintain continuously within a group (James, 1951; Dunbar, 1993). The individual interaction decreased when the group size increased (Chen & Willits, 1998; Fahy, 2001b).

Size is a major structural determinant of the level of interaction that can be expected for a given network (Fahy, 2001b). Fahy (personal communication, February 25, 2010) pointed that group size was central to the concepts of density and intensity in interaction:

> Often, we work with groups of moderate size (10 to 20), but there is a great deal of difference between group of these sizes, when it comes to interaction possibilities, and the logistics of both participation and moderation. Our (and the participants') expectations should be based on what is both possible and feasible… When groups exceed a certain size, is it any longer realistic or reasonable to expect interaction among all at the members of the group? If not …, how do we sub-divide the group so that meaningful interaction can occur? How do you structure the interaction you expect and require? What expectations should there be?

Orellana's (2006) report on the relation between class size and interaction indicated that the proper class size for an online college course taught by a single instructor was approximately 20. However, 16 was the best class size for obtaining optimal levels of interaction. On the other hand, a noteworthy number from James' (1951) study on the size determinant in small group interaction was that groups of five and above were very unstable and would quickly divided into subgroups in freely forming groups such as the groups forming in social context.

Interaction and learning styles.

To examine the differences in learning style in relation to observable features of online interaction, Fahy and Ally (2005) conducted a study using Kolb's Learning Style Inventory (LSI) and

TAT. The results found that a great portion of the interaction patterns assessed with TAT were consistent with the predictions of the Kolb model. The study found that the Convergers who preferred practical, moderated, content-oriented discussion with little socializing seemed most comfortable with the online network; and the Accommodators, who were risk-takers and preferred learning by feeling and doing, were less involved. These findings were also consistent with the result of the previous research (Rourke & Lysynchuk, 2000) that the Convergers were scored highest while the Accommodators were scored lower on achievement in online learning. The educators from both studies speculated that hypermedia and online environment favor those able and willing to engage in public interactions.

Dede (2005) argued that learning styles of the learners have shifted significantly by the informational technology; thus, instructors must allow themselves to experience new digital environments and new learning styles to continue effective teaching as the nature of students alters.

Gagné (2005, p. 329) indicated that since the online environment tended to have a less hierarchical approach and use more collaborative learning, learners who do not learn information in a systematic or linear fashion and learners who prefer independent learning will find themselves comfortable in the online environment. However, Gagné pointed out that people often learn through a combination of styles.

Educators also found that while supporting different learning styles of the learners, the web-based learning environment is reforming learning styles simultaneously due to the limited interactive features provided by the digital environment at different times (Dede, 2005; Ng'ambi, 2006).

Interaction and genders.

What differences in interaction style existed between women and men? Herring's study (1992) showed that women contributed far fewer times than men did in the discussion and women's average words per contributions were only half as long as those of the men in the LINGUIST list. Herring concluded that women tended to avoid adversarial communicative preferences and that led women to

avoid participating in interaction in computer-mediated discourses. In 1996, Herring analyzed the electronic messages posted publicly by women and men to two listserve discussion groups. The results revealed that both men and women structured their messages for the purpose of exchanging views rather than exchanging information. The evidences from her study further suggested that members of the minority gender shifted their style in the direction of majority gender norms. Although women and men negotiated information exchange and social interaction in gendered ways, Herring found no support for the stereotype that women are less interested in the electronic exchange of information than men, or that men do not use computer networks for social interaction.

While Herring's studies were mostly based on the informal learning context (listservs), Fahy's studies on gender differentiations were based on formal learning contexts. Fahy (2002) found that women preferred epistolary interaction while men preferred expository interaction in a computer conference. However, Fahy noted that gender itself is not sufficient explanation for all the different patterns in interaction.

Interaction and technology.

Web-based learning relies on technology to deliver teaching and learning. The impacts of interactive media have become dominant in teaching and learning (Fahy, 2008). Educators used technology to help developing and evolving community, facilitating individualized learning, reducing transactional distance, and enjoying greater participation equality (Fahy, 2008; Moore, 1991; Walther, 1996). Technologies facilitate distance educators to design more and better engaging activities that allow learners to exchange real-time data, deliberate alternative interpretations, and use collaboration tools to evolve new conceptual frameworks in a virtual environment. Walther (1996) suggested that rich media such as video conference are better for highly equivocal tasks while lean media such as e-mail are more efficient for less equivocal tasks. Less social cues force the group discussion to be more task-oriented.

There is a large quantity of discussion on how technologies can improve interaction, thus producing better learning outcomes (Dede, 1996 & 2005; Fahy, 2004 & 2008; Kozma, 1994; Mayer, 2001a & 2001b). Bernard, Abrami, Lou, Borokhovski et al. (2004) studied the differences between classroom and distance instruction. They found that what the learner does with media was more important than what the teacher does. The finding supported Mayer's (2001a) advocacy for a more learner-centered and less behavioral approach in instructional interaction design considering how the human cognition works and how information is processed in human mind.

Walther (1996) found that, in CMC, the message receivers tended to idealized and inflated perceptions they form about their partners; and the message senders tended to optimized self-presentation to impress their partners. He claimed that CMC had no problem with providing both impersonal and interpersonal experiences that the participants could communicate as desired.

Dede (2005) pointed out that it is oversimplified to see computers and telecommunications as a single medium that fosters a particular approach to learning. He claimed that Internet-based educational media such as experiential websites for informational learning, a multi-user virtual environment, and videoconferencing enabled learners to learn in a manner well suited for them. Dede reminded that the educators must carefully consider how to avoid possible side-effects of too many market-driven technologies and high level surveillance.

Other educators have stated their worry about not enough emphasis on pedagogy and instructional design (Wiske, 1998; Kozma, 1994); less regard for learning theory and instructional theory (Clark, 1994); lack of studies in situated use of media (Garrison, 2000); and the complexity of systems and interfaces (Fahy, 2004).

Implication for Good Practices

Interaction itself does not guarantee engagement (Garrison & Cleveland-Innes, 2005; Wagner, 1994). How can the studies introduced above be moved from theory to practice? First, the studies could be used to direct the educators to structure and design their courses. Second, the models could

be used as the tools for assessing interactions. By doing so, educators could detect the problems of teaching and identify the opportunities for improvement. Following are a few examples.

- Moore's (1989) distinction between three types of interaction can serve as a useful guide for designers in looking for appropriate interaction to foster critical thinking.
- Bales' IPS (1950) approach can be used to identify the task and social-emotion elements existing in a particular learning context so that the instructors could better fulfill their pedagogical, managerial, and social roles (Berge, 1995) using different types of interactive intervention.
- Garrison's critical thinking model and its derivative model, the Community of Inquiry, offer practical guidelines for teaching in web-based environments.
- Gunawardena and Anderson's IA Model and Garrison's critical thinking model can be used to measure how new knowledge is co-created and distributed through the processes of negotiation in group communication and identify the missing elements.
- Fahy's TAT would be helpful in detecting how learners interact with the instructors, the content, and with other learners in terms of depth and width, e.g., which or whose message gains a higher amount of responses; who is the highly connected person; whose messages are often referenced by other messages; how individuals reciprocate to each other's messages; and to what extent the topic has been cultivated intensively.
- Shaffer's ENA model would be a useful approach in investigating the interactions in a highly dynamic learning context to understand the skills, strategies, and values that the learners have developed or changed.

Other Studies on Interaction for Good Practices

Can interaction really improve learner achievement?

Bernard et al. (2009) combined the results of 74 empirical studies on web-based learning completed between 1985 and 2006 in a meta-analysis study. They found all three types of interaction

defined by Moore (1989) have positive impact on learner achievement. Increasing the strength of interaction treatments affects achievement outcomes. The study also found that learner- content interaction showed higher added values either when it was adopted alone or when it was combined with other interaction treatments. However, the study from Garrison and Cleveland-Innes (2005) found instructor-learner and learner-learner interaction are especially essential to a socially satisfying outcome.

Does one interaction intervention fit all?

Educational technology that has created a vast range of optional interaction has also set forth a challenging question of interaction choices. To answer the questions, "Which students studying what types of content under what conditions and using which instructional design benefit most from the interactions?" educators (Chen & Willits, 1998; Fahy, 2001c) found that not all interactions are equally useful and should be adjusted to individual needs and preferences as well as teaching context. Walther (1996) has suggested the appropriate match of medium and task. Fahy (2009) also argued that not all interaction is positive in terms of collaboration, communication, and cooperation and the type and amount of interaction must be designed to the capacity of the learners and their needs. Rhode's study (2009) echoed the argument that not all forms of interaction are equally valued by learners or effective due to learner preferences.

Anderson (2003b) argued that there is no single "best way" to use interaction and the best interaction for a particular context is the interaction that has the rightmix of interaction. Anderson (2003b) proposed an Equivalency Theorem of Interaction: "Deep and meaningful formal learning is supported as long as one of the three forms of interaction is at a high level. The other two may be offered at minimal levels, or even eliminated, without degrading the educational experience" (p. 3). Bernard et al. (2009) found strong support for Anderson's theorem in their study. Anderson predicted that the learner-instructor interaction would be forced to reduce due to the cost and substituted it with learner-learner and learner-content interactions. New online instructors should get familiar with all

types of interaction so that they would know how one type of interaction can effectively substitute for another when the resources were limited.

Is more interaction better?

The number of resources that can be allocated simultaneously by the human mind is limited. Miller (1956) proposed the magical number seven plus or minus two as the limit on human's capacity for processing information. Instructional designers (Clark, Nguyen, & Sweller, 2005) have tested, studied and expanded Miller's rule into a cognitive load theory that suggested the instructional design for all types of content and delivery media should limit the items to the magic number to focus attention and avoid distraction.

Simonson et al. (2009) suggested that the instructor's involvement in threaded discussions should be provided only once for every four to five learner postings, then as learners take more responsibilities for their own learning later in the course, the instructor might post once for each 10 to 12 learner postings – primarily to keep the discussions on track.

Discussion and Conclusion

This paper describes several instruments that are currently available for analyzing interaction in web-based learning. Each instrument has its special focus of attention. For example, models from Garrison and Gunawardena et al. concern more about how internal thoughts among group member are processed; and models from Fahy and Shaffer et al. concern more about what objective evidences inform the levels and spread of interactions. Practitioners should select the instruments base on the questions they want to answer and the context in which the questions occurs. The primary contribution of this study is to present the variety of options for educators in selecting proper tools for practice. Although previous research activities rarely covered the domain of elementary and secondary school applications, most of the basic principles of interaction discussed in this article are feasible for various contexts.

In the meanwhile, it might not be practical to consider interaction as an isolated issue independent from factors such as gender, learning styles, technologies, and group size. Group learning interaction should be considered as a complex system that can only be understood with mixed methods. The analysis models help educators understanding learning interactions. A single dimensional approach might lead to surface interpretations.

As next steps, more research efforts are suggested to invest in the interaction-in-action in order to facilitate the instructors who teach in technology-based and scenario-based simulative learning environments when the dynamic digital learning environment is increasing popular today.

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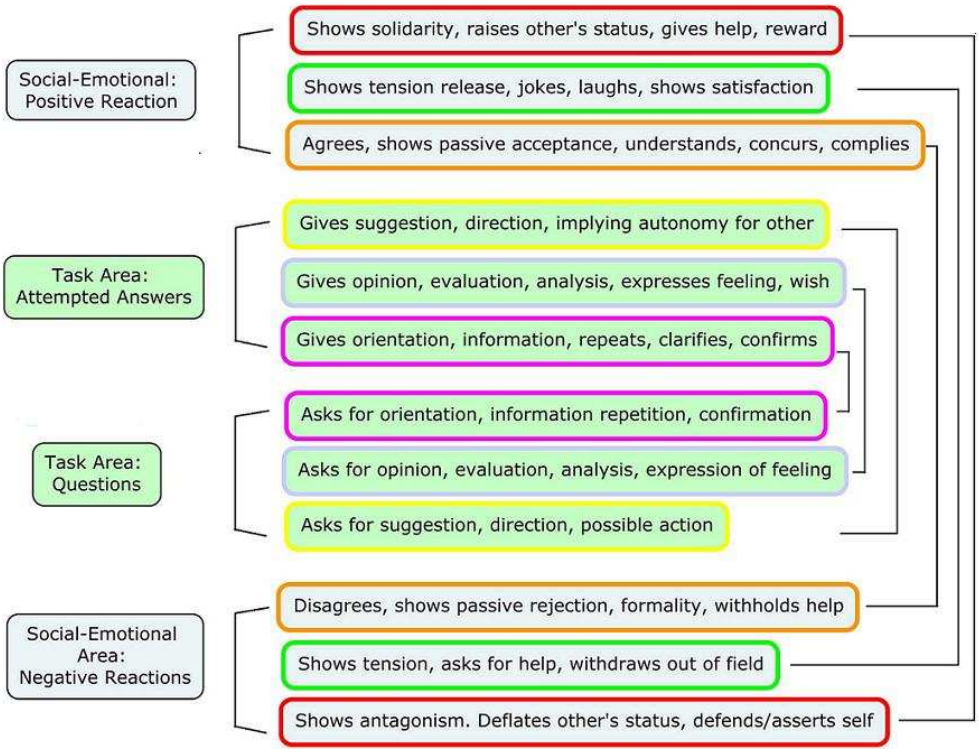
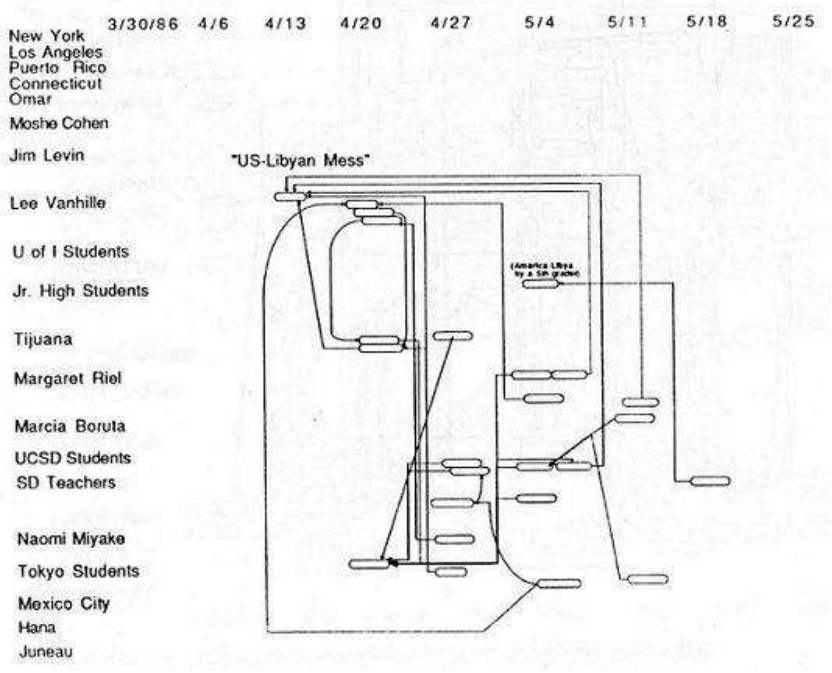
Appendix A Bales' Interaction Process Analysis

- The System of Categories –



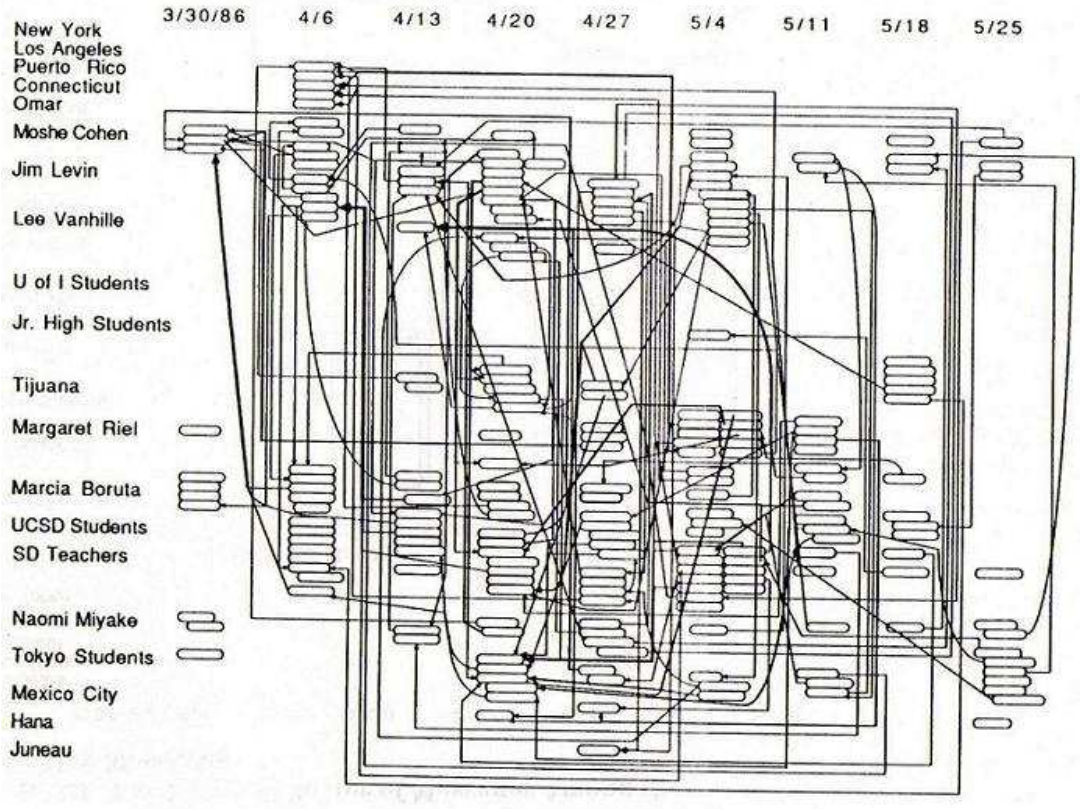
Based on Bales, R. F. (1950). A Set of Categories for the Analysis of Small Group Interaction. *American Sociological Review*, *15*(2), 257-263.

Appendix B A Simple Message Map



From Levin, J. A., Kim, H., & Riel, M. M. (1990). Analyzing Instructional Interactions on Electronic Message Networks. In Harasim, L. (Eds.), *Online Education, Perspectives on a New Environment* (pp. 185-213). New York, NY: Praeger Publishers. Each rounded rectangle is a message and the arrows point the direct links between the messages.

Appendix C A Complicate Message Map



From Levin, J. A., Kim, H., & Riel, M. M. (1990). Analyzing Instructional Interactions on Electronic Message Networks. In Harasim, L. (Eds.), *Online Education, Perspectives on a New Environment* (pp. 185-213). New York, NY: Praeger Publishers.

Appendix D Categories of Transcript Analysis Tool

Question asked		Category		Information
Modes of interaction	Sentence types	Question	Vertical	Exploring correct answers
			Horizontal	Helping to provide alternate answers
		Statement	Direct	Didactic; Providing fact, value, beliefs, etc.
			Answers / Comments	Referring to specific preceding statements
		Reflection		Expressing personal thoughts, judgments, opinions, or information
		Scaffolding		Initiating, continuing, or acknowledge interpersonal interaction
		References, authorities	References, quotations, paraphrases	Quotations or paraphrases of others' words or ideas
			Citations, attributions	Citations or attributions of quotations
Structural exchange patterns	Elements	Network size		What level of involvement is feasible for a given network; Number of potential person-to-person linkage.
		Density		Levels of person-to-person linkage; How well a group of people connected?
		Intensity (evidences of involve-ment)	Levels of participation	To what degree, on average, participants exceed the required times for participation by the course
			S-R Ratio	Levels of the reciprocal interaction among the participants
			Persistence	How long the participants persist in a threaded discussion; The personal investment of the participants to a particular topic

Based on Fahy, P., Crawford, G., & Ally, M. (2001b). Patterns of Interaction in a Computer Conference Transcript. *International Review of Research in Open and Distance Learning*, *2*(1).

Appendix E Mathematical Formulas in TAT

Density

Density (D) = 2a / N(N-1)

Where a = the actual number of interactions observed, and N = the number of participants in the network.

Total possible number of messages sent or received by one participant = N(N-1) / 2

Example: If the number of participants was 13. The actual number of interactions observed was 61. Then the value of the density will be

D = 2 x 61 / 13(13-1) = 0.782 = 78%

Intensity

Level of Participation (L)

L = the average number of student postings / the requirement for participation

S-R ratio

S-R ratio = message sent / message received

Persistence (P)

P = the number of messages appeared in the tread of a discussion, from the first posting on the topic to the last (the topical progression).

Initial posting

Level 2

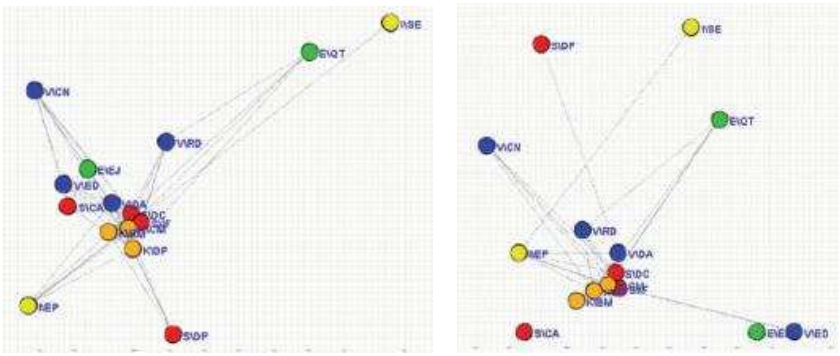
Level 3

Level 4

Etc.

Based on Fahy, P., Crawford, G., & Ally, M. (2001b). Patterns of Interaction in a Computer Conference Transcript. *International Review of Research in Open and Distance Learning*, *2*(1).

Appendix F Network Graphs in Epistemic Network Analysis



From Shaffer, D. W., Hatfield, D., Svaronvsky, G. N., Nash, P., Nulty, A., Bagley, E., et al. (2009). Epistemic Network Analysis: A Prototype for 21st Century Assessment of Learning. These two graphs show the changes in the relative centrality and the relative distance between elements (bubbles) of an individual over time.