

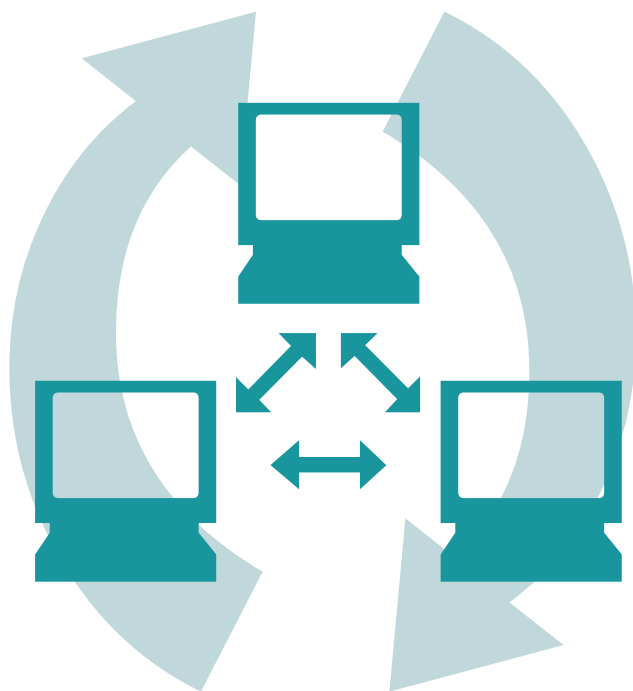
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GAUGING AND IMPROVING INTERACTIONS IN ONLINE SEMINARS FOR MATHEMATICS COACHES



Cathy Bonus Lalli and Stephanie Feger

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■ Abstract

A key characteristic of both high-quality professional development and successful online learning communities is peer-to-peer interaction. This paper describes the results of a study in which we examined the quality of peer-to-peer interaction among diverse groups of geographically dispersed educators in an online professional development project called Investigations Online. Using mixed methods, the study examined data from online seminars designed for mathematics coaches to support implementation of the standards-based, elementary school curriculum, Investigations in Number, Data, and Space. In this paper, we describe key elements for assessing the quality of the peer-to-peer interaction in online seminars as a function of three factors (interaction patterns, word quantity, and discussion levels). Analyses of these three factors provided a systematic way to compare interaction across a series of seminars. We report on design changes to the seminars and their impact on peer-to-peer interaction. In particular, results showed the effectiveness of the change in seminar format and discussion strategy to rotating responsibility for peer-led discussions on seminar topics.

■ INTRODUCTION

■ Support for Professional Learning

Ongoing learning opportunities that include interaction with peers and access to timely feedback are recognized as keys for improving practice in the teaching profession (Bransford, Brown, & Cocking, 2000). With the emergence of the Internet as a vehicle for enabling interaction, online learning has the potential to meet particular needs and interests of teachers regarding specific content or curriculum. Online professional development offers access to people and information at a convenient time and place and can provide opportunities for a sustained effort to plan, test out, and exchange ideas with colleagues on how certain practices are working (Harasim, Hiltz, Teles, & Turoff, 1998).

Based on the need for teacher development in key content areas such as mathematics, and the growing interest in the design of virtual environments as a means to support professional learning (Barab, Kling, & Gray, 2004), The Education Alliance at Brown University has developed online learning opportunities to support K–12 educators. Our work broadly addresses how online technologies can create and support professional learning opportunities and, more specifically, explores the patterns of use and productive features that emerge in these online settings. One such project, Investigations Online, is designed to support mathematics teachers and coaches from different schools and districts with the implementation of the elementary school curriculum, *Investigations in Number, Data, and Space*.

This paper describes the design features of an Investigations Online seminar for coaches entitled, *Leading the Way: Coaching Teachers Using Investigations*, and presents the results of a study that focused on one feature of the design: peer-to-peer interaction. In particular, this study allowed us to examine how design changes in the discussion format and strategies affected the quality of peer-to-peer interaction. Using a mixed methods approach, we operationalized the concept of interaction as a function of three factors (interaction patterns, words per message, and discussion level). We developed a systematic way to analyze each factor and applied the complete process methodology to the archived discussions of each seminar, providing a basis of comparison across the series. This study was an effort to assess the quality of asynchronous discussions, establish a benchmark for interaction quality in future seminars, and provide the basis for improving design features in online professional learning.

■ Project Background

Online Learning to Meet the Needs of Mathematics Coaches

The online seminars were designed to support the professional learning needs of coaches who guide mathematics teachers in implementing the *Investigations* curriculum. Coaching is an emerging and complex role, and those assuming this responsibility have varying professional development needs. A coach primarily works one-on-one with teachers in the classroom using questioning and observation to help teachers improve their practice (Showers & Joyce, 1996). For teachers assuming the coaching role, this represents a new stage in their professional life, transitioning from working primarily with students to serving as a resource for teacher learning. This role can be difficult for novice coaches to grasp right away and requires new perspectives—seeing things through the “coaching eye” in contrast to the “teaching eye”—as an important step in understanding the dimensions of their task (Feger, Woleck, & Hickman, 2004, p. 14). Moreover, many coaches report that in their role as specialists they are often isolated in their work, and “would benefit from professional learning communities of their own” (Richard, 2003, p. 3). Through inquiry and dialogue in the *Investigations Online* seminars, participants could exchange their knowledge and resources with others undertaking similar work and compare their experiences with those of the wider learning community.

Online Seminar Structure

In designing and evaluating several cycles of the seminars, we framed our work in terms of the related methods of “development research” (van den Akker, 1999; Reeves, 2000) and “design research” (Shavelson, Phillips, Towne, & Feuer, 2003; Collins, 1992; Edelson, 2002). Both methods approach work as an ongoing series of design experiments that address emergent issues (Collins, Joseph, & Bielaczyc, 2004; Collins, 1992; Brown, 1992). Shavelson et al. add that implicit in design studies is an iterative development cycle, with knowledge developed and refined through question-driven methods, and that the focus of work in design-based studies is often “in new teaching and learning technologies” (p. 25). They also state that “the strengths of design studies lie in testing theories in the crucible of practice; in working collegially with practitioners, co-constructing knowledge” (p. 25). We have used this approach to guide the development of the *Investigations Online* seminars, testing them over multiple trials and using analysis of data from the seminars to inform design changes.

We structured the overall seminar design around three critical features: learning materials, facilitation, and peer-to-peer interaction, defined as follows:

- 1 Learning materials, including case studies of critical incidents in coaching and research articles;
- 2 A facilitator who uses strategies that foster interaction and learning in the online environment and supports the seminar dialogue;
- 3 Peer-to-peer interaction, supported by the seminar structure and asynchronous discussion tools to allow a sequenced progression of dialogue.

For the purpose of deepening our understanding of the role of peer-to-peer interaction as a critical feature of the design approach, this study focused on defining the quality of the peer-to-peer interaction in the online seminars and gauged the effectiveness of the design changes made to improve peer-to-peer interaction. While the concept of interaction is one that we will return to later in this paper, we offer a working definition of interaction as “communicative statements or acts between participants” (Strijbos, Martens, & Jochems, 2004, p. 407).

In each of the seminars examined in this study, the same facilitator guided participants through weekly assignments, reflections, and online discussions exploring the skills and strategies of the coaching role. The same online environment was used for each seminar, as well. SiteScape Forum, a proprietary discussion and document forum, enabled threaded discussions and displayed documents in several formats. Throughout the seminar, participants analyzed case studies based on incidents of classroom practice and teacher–coach interactions. The case studies served as a catalyst for discussion and provided an opportunity for participants to reflect upon the decisions and issues that emerged in their own coaching practice. Through these activities, participants were able to evaluate aspects of the coaching role and discuss what features and circumstances made the intervention effective or ineffective. During the last two weeks of the seminar, participants drafted a sample case study developed from their own coaching interactions and shared this with the group for discussion.

Seminar discussions focused on how coaches can serve as both a resource for deepening practitioners’ mathematical content knowledge and a guide for building teacher understanding of the *Investigations* curriculum (Feger et al., 2004). In post-seminar feedback, participants expressed an interest in gaining access to the “bits and pieces” of ideas from other participants and making use of these ideas in their own practice. Many participants noted that it was through the diversity of viewpoints presented in the seminar that they were able to broaden their awareness of *Investigations* implementation across grade levels and acquire new understandings of how mathematical ideas develop over time. Thus, the seminar offered a structure for interaction that enabled participants to test their approaches to problem solving with one another, to reflect on new information, and to build knowledge together.

Discussion Change: Peer Discussion Leaders

Participant feedback on the first two seminar cycles indicated that “the opportunity to read the case studies and learn from others’ reactions to them” was a valuable experience, but finding time to respond to all of the cases was difficult to manage. In response, we changed the seminar discussion format and strategies to distribute the case analysis activity and encourage participants to take on the role of discussion leader.

We implemented this design change in the third seminar cycle. The facilitator introduced and guided the adoption of the new discussion strategy. Each week, three or four participants were the designated discussion leaders for the cases. These discussion leaders were responsible for posting their responses to the cases and the focus questions, closing their posting with the questions that had emerged from their reading of the case. The other participants would then read discussion leaders’ postings and compose a response in the second half of the week, adding any reflections for the group to consider. The facilitator would join in the discussions by synthesizing responses, raising new questions, asking for clarification, or suggesting topics for further discussion. The use of peer discussion leaders was intended to promote dialogue among participants in the group, and, as the facilitator explained, it also allowed for a shared ownership of the seminar to ensure that all of the voices were being heard.

Theoretical Perspectives

Our design approach and this study are grounded in strands of research and literature on high-quality professional development (Sparks, 2002; Elmore, 2002; Ball & Cohen, 1999); online learning communities (Lave & Wenger, 1991; Wenger, 1998); and theories of social interaction (Strijbos et al., 2004; Rourke, Anderson, Garrison, & Archer, 2001a). This section describes their connection in light of key concepts in designing online learning environments.

Distributed competence in online learning. The ability to tap into the expertise of others who share common interests or possess vital knowledge, but who are geographically dispersed, is valuable in many professional contexts and in everyday life. Harkins and Kubik (2000) described education as the immediate application of knowledge “to successfully complete decisions and tasks anywhere, any time...” (p. 11) by accessing expertise through technology (which they described as distributed competence). Orlikowski (2002) studied the characteristics of geographically dispersed high-tech organizations that operated on a global scale and found that professional expertise was spread across these disparate groups. She identified this as distributed competence (p. 269), or “know-how” that was evident in the collective capabilities of individuals and fostered through peer-to-peer

exchanges and communications between novices and experts. Schlager, Fusco, and Schank (2002) recognized a similar concept in the success of online communities that crossed organizational boundaries to engage participants who shared many similarities and differences.

According to Wenger (1998), these groups, defined as communities of practice, provide a means by which professionals share their expertise and work together as an authentic way of learning and communicating about the workplace. In the field of education, studies show that the diverse perspectives of all participants can enrich the professional development experience for teachers; this is especially true when networked learning communities extend beyond the walls of local schools to include other colleagues and leaders in the profession (National Commission on Teaching and America's Future, 2003). For schools using a common curriculum and seeking to improve their performance, a community of practice that draws upon the distributed competence of educators may have important implications for professional learning in a discipline.

Teacher collaboration in online activities. Furthermore, collaborative work with colleagues is a key characteristic of high-quality professional development precisely because such collegial collaboration promotes a shared focus on the content and activities that are closely tied to classroom practice (Sparks, 2002; Elmore, 2002; Ball & Cohen, 1999). The concept of collegial collaboration falls within the domain of social-constructivist learning that relies on learner-centered strategies to promote engagement among participants, between participants and facilitator, and between participants and content in authentic contexts that are meaningful to the learner (Vygotsky, 1978; Papert, 1993; Piaget, 1970). These strategies require social interaction, which is variously described as cooperative or collaborative (Strijbos et al., 2004). Moreover, learner-centered strategies are essential to the development of online learning communities (Lave & Wenger, 1991; Wenger, 1998): Interaction sustains the community and supports participants in their learning through common tasks and shared experiences.

Collective participation is a social process that facilitates learning by engaging with other people around a common task or joint activity that requires group participation and responsibility (Johnson & Johnson, 1987; McCombs, 2001; Barab et al., 2001; Koschmann, 2002). Authentic activities, sometimes based around case studies, provide a basis for “ongoing professional communication” (Garet, Porter, Desimone, Birman, & Yoon, 2001, p. 928) in which teachers share methods and discuss what they have learned, as well as how to apply it in practice. Additionally, interaction and dialogue among participants are cited as significant features for eliciting high levels of inquiry and knowledge building in online learning communities (Palloff & Pratt, 1999).

Cultivating interaction among participants who are geographically disperse, however, is a challenge and a primary consideration in the design of online activities. In order to support professional development, online activities require a focus on the social processes that promote learning (Rourke et al., 2001a) through interaction and cooperative strategies, rather than a focus on the independent learner (Cho, Stefanone, & Gay, 2002). The complex characteristics and dynamics at play in an online environment pose unique concerns. Barab, MaKinster, Moore, Cunningham, and the ILF Design Team (2001) identified social dynamics as the primary concern in designing an online community and more critical than usability. Fahy (2003) suggested that further research might connect increased interaction with enhanced learning and identified specific supportive behaviors (such as direct or indirect reference to the statements of others) that participants used in a discussion in order to increase social interaction.

Social interaction in the online environment. Online interaction is also affected by the asynchronous or synchronous (Bonk, Hansen, Grabner-Hagen, Lazar, & Mirabelli, 1998) nature of the environment, whereby asynchronous interactions more often consist of “complex ideas and depth of thought” (p. 308) and synchronous responses tend to be “more concise and egocentric” (p. 308). In fact, the exercise of written interaction in online asynchronous discussions promotes higher order thinking skills and conceptual development beyond most face-to-face environments (Lapadat, 2002). Because of the literate nature of online discussions, Gunawardena, Lowe, and Anderson (1997) stated that an analysis of discussion content is essential to assessing “the quality of interactions and the quality of the learning experience” (p. 398).

Identifying *patterns of interaction* among discussion participants is one strategy that can provide evidence for several aspects of online discourse, such as collaborative learning (Curran, Kirby, Parsens, & Lockyer, 2003), sociability (Barab et al., 2001), reasoning (Hogan, Nastasi, & Pressley, 2000), engagement (Herrington, Oliver, & Reeves, 2003) and peer-to-peer support (Fahy, 2003; Curran et al., 2003). In this study, we adopted the terminology of Hatano and Inagaki (1991) and looked at horizontal interaction and vertical interaction patterns. In addition, the concept of *levels of interaction* (Strijbos et al., 2004) identified characteristics of involvement and prompted our interest in the levels of discussions (Järvelä & Häkkinen, 2002) as an important component of interaction. Aligning the discussion levels to Bloom’s taxonomy of educational objectives (Engelhart, Furst, Hill, & Krathwohl, 1956/1966) provided us with a framework for a hierarchical order of categories that ranged from simple to complex concepts in our discussion analysis.

■ Research Study

The iterative cycle of these seminars and the consistency of a single facilitator provided the opportunity for a study to gauge the impact of discussion strategies on peer-to-peer interaction. Interaction was of special interest because participants were from a wide geographic area, rather than from a single school or district. We studied three iterations of the eight-week seminar, *Leading the Way: Coaching Teachers Using Investigations*, conducted over the past two years. Participant feedback from the first two seminar cycles prompted changes in the discussion strategies in the third seminar cycle. These changes included the creation of small subgroups and rotating responsibility for weekly discussion leaders, with the facilitator guiding this process.

An analysis of all three seminars identified and compared the levels of interaction in facilitator-led groups and peer-led groups, indicating the impact of the design changes. In order to determine a change in the “quality of interaction,” we first defined the concept in terms of three different factors—interaction patterns, number of words per message, and discussion levels. We then analyzed the data for each factor and developed a systematic way to compare the results from the lines of evidence in facilitator-led discussions with those of the peer-led discussions.

From this study, we hope to understand how changes in discussion strategies might improve future professional development seminars for mathematics coaches and teachers in varied settings, with diverse student populations, and with limited professional development resources.

METHOD

For the purposes of this research study, we developed a process methodology (Strijbos et al., 2004; Rourke, Anderson, Garrison, & Archer, 2001b) that provided a systematic way to compare the “quality of interaction” across seminars based on a set of measurable factors that were appropriate for this project. These factors were quantitative and qualitative indicators for three dimensions of interaction: (1) interaction patterns (participant discussion directed to peers or to the facilitator); (2) word quantity (number of words per participant message); and (3) discussion levels (low, progressive, high). In addition, we compared participant satisfaction levels reported on post-seminar surveys. None of these factors could stand alone as a measure of quality; however, taken together, we believe that they provide a descriptive analysis of interaction quality that was reasonable and defensible for this project.

Archived discussions revealed patterns of interaction among participants that have been defined as evidence of social and peer-to-peer communication in online discussions by many authors, including Curran et al. (2003); Fahy (2003); Fahy, Crawford, Ally, Cookson, Keller, and Prosser (2000); and Zhu (1996). In this study, we looked at horizontal interaction, defined as responses or messages among participants, and vertical interaction, defined as messages from a participant to the facilitator as the acknowledged expert (Hatano & Inagaki, 1991). An increased percentage of participant interaction would be an indicator of increased peer-to-peer support, a key factor in the quality of interaction. The percentage of interaction with the facilitator would decrease in proportion to the increase in interaction among participants.

The average number of words per message became a quantitative indicator and the next factor of interaction quality. Although we considered other quantitative measures, including the number of messages, paragraphs, sentences, or total number of words per participant, we determined that these units were less accurate measures for the following reasons. The total number of messages or words per participant did not necessarily indicate reflective, substantive content and sometimes consisted of “me, too’s” or unrelated content. Likewise, paragraphs and sentences were not reliable units of measurement, because the online writing style of participants was casual and more often flowed as conversation or trains of thought, rather than consistent constructs for publication or analysis. However, a high number of average words per message was more likely to indicate a deeper level of reflection and participation. The work of Hara, Bonk, and Angeli (2000) supported this concept by referring to lengthy messages as “one sign of depth to student electronic interaction” (p. 129).

The discussion level of each seminar provided the third dimension of quality and a triangulation of indicators. The work of Järvelä & Häkkinen (2002) provided the

methodology for rating the level of discussions from low (mostly general comments) to high (evidence of higher order thinking skills). A content analysis of the archived discussions was necessary for this methodology and also a requirement in any assessment of interaction quality (Gunawardena et al., 1997).

A thorough review of content analysis methods and complex coding schemes emphasized the importance of a method that was relevant to the task-based nature of the seminars versus an open discussion. Therefore, we decided to use an interaction-based coding system (Spatariu, Hartley, & Bendixen, 2004), whereby the messages were classified in the context of the discussion. We adapted an a priori coding scheme from the work of Järvelä & Häkkinen (2002) and used it in content analysis to identify categories of thematic units (Henri, 1992; Stemler, 2001; Rourke et al., 2001b; Hara et al., 2000) within each message. The distribution of categories determined a low (general comments), progressive (elaborations and reflections), or high (theory-based references and constructive reasoning) level of discussion, and provided a descriptive technique for the third quality indicator. As part of our adaptation, we aligned the categories to Bloom's taxonomy (Engelhart et al., 1956/1966), which ranged from concrete ("Comment," "Experience") to abstract ("New Point," "Theory") concepts. This construct helped to define and place the categories on a continuum that reflected lower to higher order thinking skills.

Taken together, these multiple data sources constituted a mixed methods approach (Reeves & Hedberg, 2003) with which to gauge the "quality of interaction" for our purposes. This was a pragmatic way to establish a basis of comparison, as discussion strategies changed across seminars.

■ Participants

For these seminars, we recruited volunteer applicants by e-mail and Web notices through the CESAME Support Site for *Investigations* and professional networks. Applications came from urban, suburban, and rural communities, as well as a few international schools. The high number ($n = 188$) of applicants for the pilot and subsequent seminars, along with positive participant feedback, confirmed the need for these seminars and their continued development. We selected seminar participants based on criteria that included (a) the active use of the *Investigations* Support Web site, (b) the degree of coaching responsibilities in their jobs, (c) at least one year's experience with the *Investigations* curriculum, (d) the socio-economic need of students, and (e) limited access to other professional development support. A total of 57 educators from 26 states, the District of Columbia, and two foreign countries participated in the first three coaching seminars. The selection rate was 30% of applicants.

Data Sources

Archived discussions provided complete transcripts of each online seminar. In each eight-week seminar, Week 1 through Week 6 addressed a new topic and included assignments, analysis of case studies, and discussion; the final two weeks of the seminar focused on the development of a final project. Because limited resources prevented a comprehensive examination of all of the archived material, the weeks with discrete topics served as a representative sample of the discussion (Rourke et al., 2001b). We randomly selected two weeks of transcripts from the first six weeks of each seminar, representing approximately 30% of the instructional portion, in order to generalize results to the entire seminar.

We analyzed the selected weeks for three lines of evidence: (1) horizontal and vertical patterns of interaction among participants, (2) the average number of words per message per participant, and (3) discussion levels. Increases in horizontal interaction, the number of words per message, and discussion levels in the third seminar compared to those of the first two seminars would indicate improvement as a result of changes in discussion strategies.

In addition, we collected and summarized participant feedback from post-seminar surveys. For the purposes of this paper, responses to two survey questions were examined: (1) respondent perception of the usefulness of interactions with peers and (2) open-ended comments that identified interaction or dialogue with others as the most useful part of the seminar. Responses to these questions contributed qualitative and descriptive data from the perspectives of participants.

Procedure

We collected and analyzed data from three seminars, conducted in spring 2002, fall 2002, and spring 2004. We prepared for each content analysis by using a master list of participants and assigning a unique identifier from a numeric series in place of each name. Facilitator messages were clearly identified with a symbol that distinguished them from the messages of participants, so that coders could quickly recognize them when analyzing interaction patterns. The transcripts of messages with identifying codes or symbols were printed for each seminar as text files with word counts at the end of each message. The average and total number of messages were calculated for each participant, as well as for the facilitator.

In the threaded discussions, response messages between peers were labeled as horizontal interactions and messages directed to or in response to the facilitator (usually seeking or agreeing with facilitator expertise) were identified as vertical interactions. Top-level messages were not coded for direction.

We used an interaction-based coding system, adapted from the work of Järvelä & Häkkinen (2002) to accommodate the purpose of this study (Potter & Levine-Donnerstein, 1999). We collapsed the number of categories from five to four to create a more reliable framework for the coders who encountered difficulty with distinguishing between the original categories of “Suggestions” and “New Point.” Examples of each category are included in the Appendix. We then aligned the categories (“Comment,” “Experience,” “New Point,” and “Theory”) to Bloom’s taxonomy of thinking skills, thereby establishing a continuum for the categories that ranged from concrete to abstract concepts, requiring lower to higher order thinking skills. We expanded the definition of each category to reflect the relevance of each to this project and added the characteristics that aligned to Bloom’s taxonomy. Table I shows the specifics of this coding scheme.

TABLE I: INTERACTION-BASED CODING SCHEME FOR CLASSIFYING DISCUSSION LEVEL

	Category Definitions	Discussion Level (adapted from Järvelä & Häkkinen, 2002)	Characteristics Aligned With Bloom’s Taxonomy
ABSTRACT ↑	THEORY – Postings are theory-based and may include mutual negotiations with other participants to clarify understanding. References to theory-based readings demonstrate higher levels of reasoning and may inspire constructive discussion.	Higher	<ul style="list-style-type: none"> ■ Assess value of concepts ■ Relate to relevant theories
	NEW POINT – Postings build on previous discussion by questioning for more detail or generating new ideas for further discussion.	Higher/Progressive	<ul style="list-style-type: none"> ■ Use information for problem solving ■ Introduce new perspectives ■ Extend original concepts ■ Synthesize information to create new meaning
	EXPERIENCE – Postings reflect personal or professional experiences and may build on previous discussion.	Progressive	<ul style="list-style-type: none"> ■ Interpret knowledge through experience ■ Translate topics to new contexts
↓ CONCRETE	COMMENT – General remarks may paraphrase, reflect, or interpret previous material, but do not substantiate or add new information or ideas. They may also include independent opinions.	Lower	<ul style="list-style-type: none"> ■ Superficial, unsubstantiated comments ■ Working knowledge of topic ■ Understanding not connected to larger concepts

Two coders trained together to learn the coding scheme for identifying thematic units, or units of meaning, within each message. Working from the discussion transcripts, coders independently assigned the thematic units to the appropriate categories one week at a time. Holsti's coefficient of reliability (Rourke et al., 2001a) was used to calculate percent agreement for inter-rater reliability (IR). IR averaged 88% for the project and ranged from 82% to 92% for weekly coding. Coders re-visited units in disagreement and negotiated the appropriate category.

We determined the frequency of each category in each seminar and then compared the percentages for categories in peer-led discussions to those of facilitator-led discussions. The proportion of categories in each seminar determined its discussion level (low, progressive, and high), as shown in Table II.

TABLE II: DISCUSSION LEVELS DEFINED BY PROPORTIONS OF CATEGORIES

		Discussion Level	Categories
ABSTRACT	↑	High	{Theory + New Point} > 33%
		Progressive	{New Point + Experience} > 50%
		Low	Comment > 50% and Theory < 2%
CONCRETE	↓		

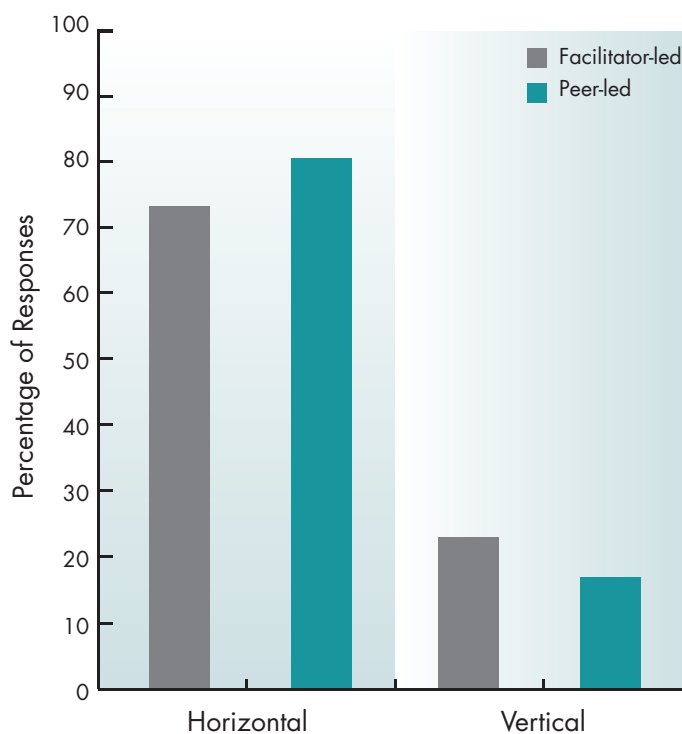
RESULTS

Results from our analysis, formative feedback, and post-seminar surveys all suggested that the discussion changes made in the third seminar, including the creation of small subgroups and the rotation of weekly discussion leaders, were positive.

We developed an exploratory process to define and gauge the quality of participant interaction as the dependent variable in this study. Our definition of interaction quality consisted of quantitative and qualitative factors for three dimensions of interaction: interaction patterns, the average number of words per message, and discussion levels. We also analyzed levels of participant satisfaction. We compared the data from the first two seminars (Seminar 1, $n = 16$; Seminar 2, $n = 16$) of facilitator-led discussions (total $n = 32$) to the data from the third seminar of participant-led discussions ($n = 19$).

Horizontal and vertical patterns provided evidence of interaction within the group. The percentage of horizontal interaction increased to 81% in the peer-led discussions, compared to 74% in the facilitator-led discussions (see Figure 1). Viewed as percentages, an increase in horizontal interaction meant a decrease in vertical interaction in the peer-led group. It is interesting to note that although interaction with the facilitator decreased in the peer-led group, the percentage of facilitator messages (as a proportion of all messages) increased for that group.

FIGURE 1. COMPARISON BETWEEN FACILITATOR-LED AND PEER-LED DISCUSSIONS BY INTERACTION PATTERNS



As stated previously, the average number of words per message provided a basis of comparison that was more indicative of quality than other measures. Our calculations showed that participants in the peer-led discussions averaged 362 words per message, while facilitator-led discussions averaged 275 words per message for an increase of 32%.

We tallied the number of thematic units in each category for each discussion week and compared the percentages of categories. See Figure 2 for facilitator-led categories and Figure 3 for peer-led categories. As shown in Figure 2, the category of “Comment” comprised more than half of all the coded units in the facilitator-led discussions. The two categories closest to the abstract end of the continuum, “New Point” and “Theory,” combined to total 14% of all coded units, with “Theory” comprising only 1%. In comparison, Figure 3 illustrates a decrease of 17% in the proportion of “Comment” units in the peer-led group. The combined percentages for the two more abstract categories were 28%, twice that of the facilitator-led groups.

FIGURE 2. PERCENTAGES OF DISCUSSION CATEGORIES EVIDENT IN FACILITATOR-LED DISCUSSIONS

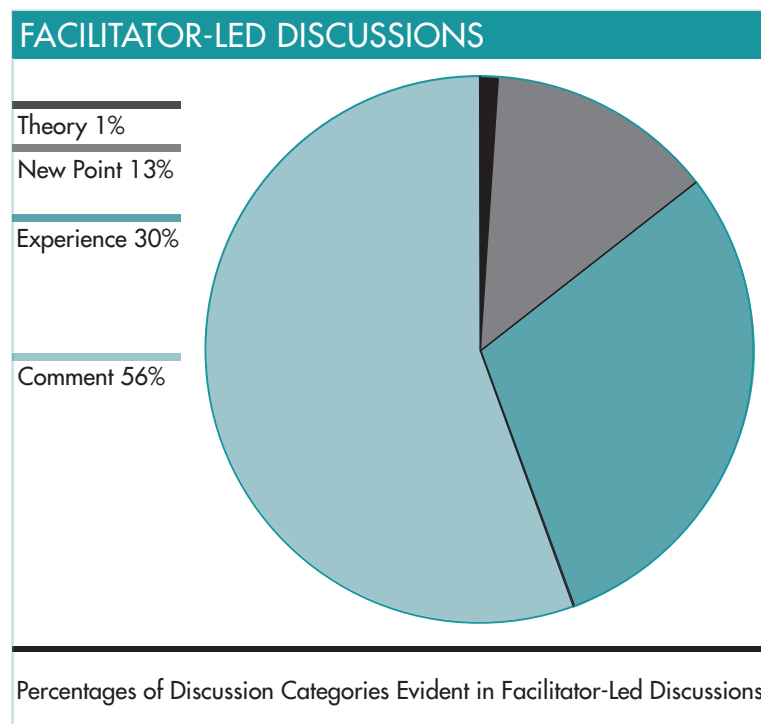
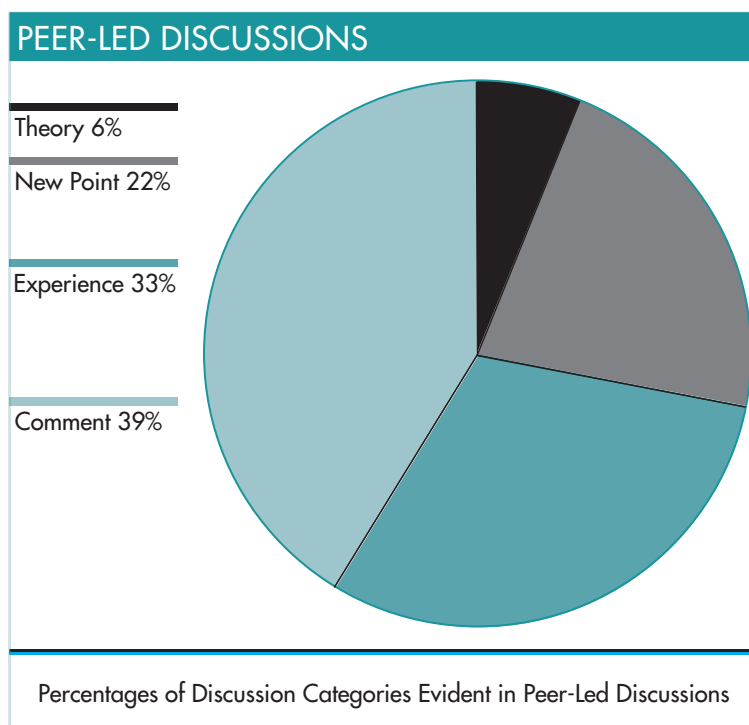
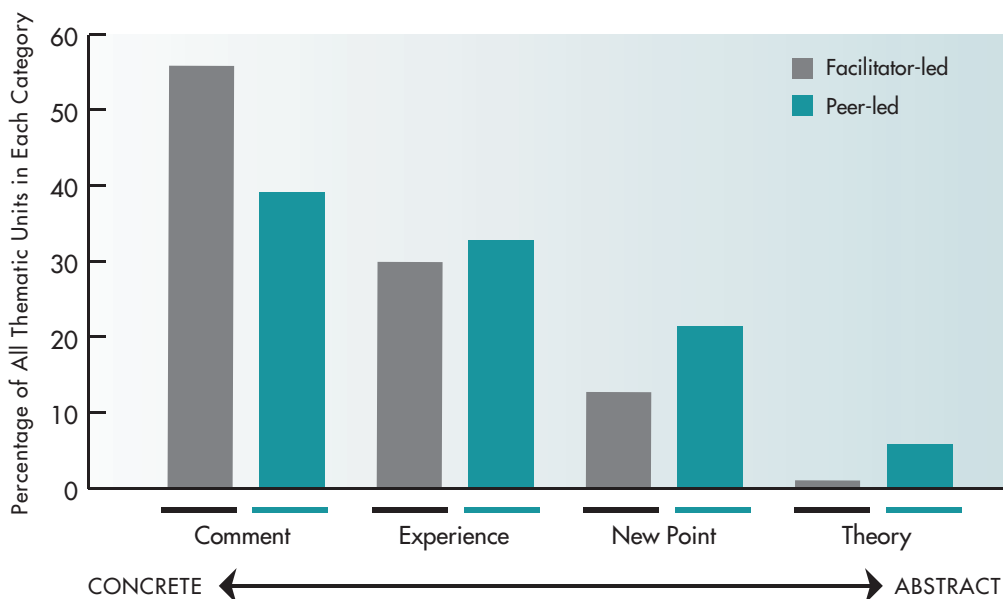


FIGURE 3. PERCENTAGES OF DISCUSSION CATEGORIES EVIDENT IN PEER-LED DISCUSSIONS



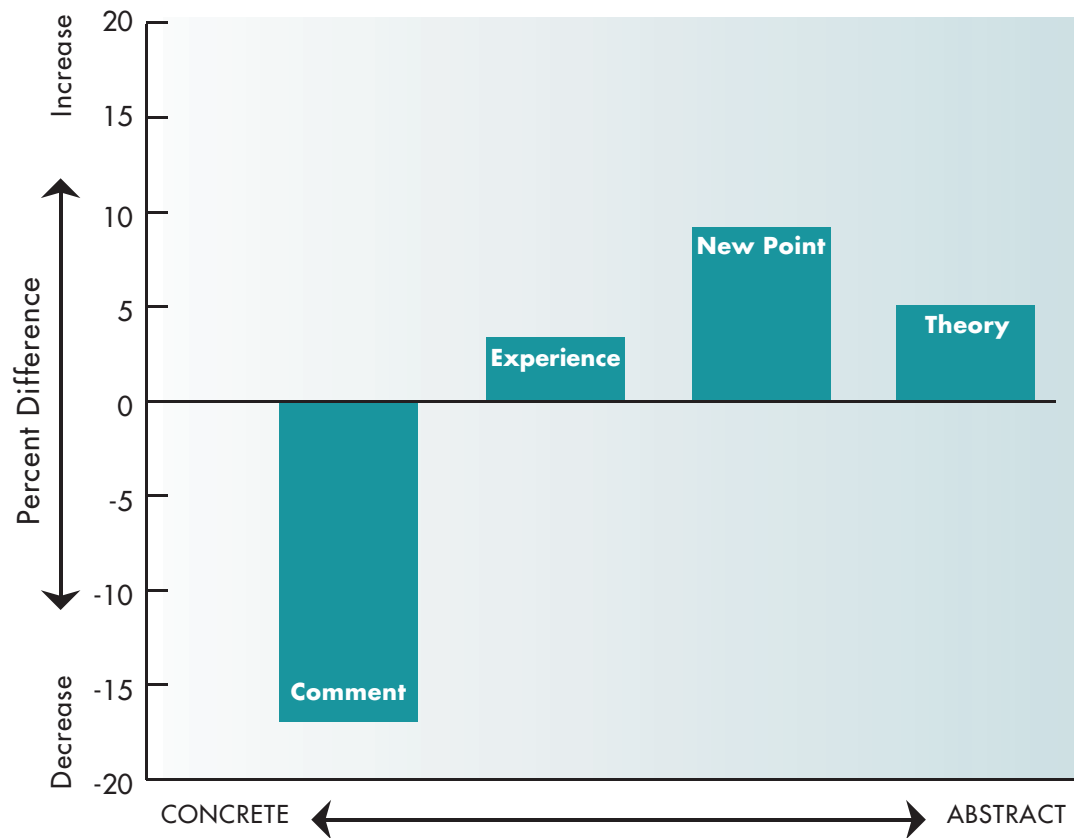
From another perspective, Figure 4 shows a comparison of categories for each discussion. A reduction in “Comment” is clearly evident in the peer-led discussion, along with increases in all three of the higher order areas.

FIGURE 4. COMPARISON OF THEMATIC UNITS IN EACH CATEGORY BY DISCUSSION



The comparisons for each category in Figure 4 are displayed in another format in Figure 5. The differences between the peer-led and facilitator-led discussion groups are shown as a decrease or increase in each category. For example, the “Comment” category decreased by 17% and the “Theory” category increased by 5%. Figure 5 illustrates the increase in more abstract categories for the peer-led group.

FIGURE 5. THE DECREASE OR INCREASE IN EACH CATEGORY FOR THE PEER-LED GROUP, BASED ON THE DATA IN FIGURE 4



In addition to the three major indicators described above, participant feedback from two post-seminar surveys provided another source of qualitative information. One question asked participants to rate the usefulness of “conversations and discussion with other participants around issues that emerged in the seminar dialogue.” Likert-scale responses ranged from 1 (not at all useful) to 5 (very useful). The average score from participants in the facilitator-led groups was 4.5, while respondents from the peer-led group scored 4.8. Another item invited open-ended comments to the question: “What was most useful about the seminar in terms of your own professional development?” In the facilitator-led group, 60% of respondents identified interaction or dialogue with others as the most useful part, compared to 89% of the peer-led group. In both groups, reading and case study materials were identified as the second most useful part of the seminar.

Table IV summarizes the lines of evidence presented in this section.

TABLE IV: EVIDENCE SUMMARY

LINES OF EVIDENCE	Facilitator-Led Group (n = 32)	Peer-Led Group (n = 19)
1 Patterns of Interaction – Horizontal – Vertical	74% 26%	81% 19%
2 Avg. Words Per Message	275	362
3 Discussion Level	Low	Progressive
4 Participant Feedback – Usefulness of interaction – Interaction as most useful part of seminar	4.5 60%	4.8 89%

DISCUSSION

Our results supported our expectations that the changes in discussion format and strategies would improve the quality of interaction among participants. The results also provided evidence that a diverse group of educators from various geographic locations could interact effectively and benefit from online, asynchronous professional development.

Using a mixed methods approach, we gauged three dimensions of interaction (patterns of interaction, word count, and discussion level) that together provided evidence of quality of interaction for this project and a basis of comparison for changes in discussion strategies in three online seminars. Two conditions minimized the variability within this project: (1) a consistent seminar structure and (2) the same facilitator leading all of the seminars. In addition, self-selected applicants and an established selection process ensured comparable groups for each seminar, even though participants were from various geographic areas.

The patterns of interaction showed a 10% increase in horizontal responses for the peer-led discussion, indicating more social interaction and peer-to-peer support than in the two facilitator-led discussions. These results were interesting in light of the fact that the number of facilitator messages constituted a larger percentage of all seminar messages in the peer-led group than in the facilitator-led group.

The average number of words per message increased 32% in the peer-led group (362 words, compared to 275 words for the facilitator-led group). This increase might suggest a deeper level of understanding and reflection on the part of the discussants.

A content analysis coding scheme identified thematic units in the discussion messages and assigned the units to categories that ranged from concrete to abstract concepts. Differences between the peer-led and facilitator-led groups showed improvement in the peer-led group with a decrease in the percentage of thematic units in the “Comment” category and increases in the percentages of units that required more abstract concepts and higher order thinking skills. In fact, the highest two levels of categories (“New Point” and “Theory”) for this group combined to comprise 28% of the coded units in peer-led discussions, twice the amount for the same categories in facilitator-led discussions (see Figure 2). The distribution of units among higher categories advanced the discussion for the peer-led group to a progressive level.

Taken together, these factors supported the value of the peer-led discussion strategy and provided evidence of improvement in peer-to-peer interaction. In addition, post-seminar surveys showed that participant perceptions of the value and usefulness of their online interactions increased for the peer-led group.

■ Limitations

The limitation of these data sources is that they are relevant to only a self-selected group of motivated educators who actively used the *Investigations* curriculum and who had previous experience in mathematics coaching. The self-selection of participants, their learning styles, and their preferences for particular learning media are critical factors. Therefore, these results on the quality of engagement in online professional development, while important to the future of this and related projects, do not suggest a comparison to other online projects or to face-to-face discussions.

Another limitation of this study concerns the random selection of two weeks of archived transcripts from the first six weeks of each seminar. Herrington, Oliver, and Reeves (2003) suggest that patterns of engagement may be affected by the online learning experience of participants, such that the engagement of novices may be delayed due to their reluctance to contribute in the early sessions. Therefore, it is possible that the quality of interaction would be better in later weeks for all seminars. Future studies could address the same weeks, such as Weeks 2 and 5, from each seminar.

■ Validity and Reliability

A mixed methods approach to gauging interaction resulted in qualitative and quantitative factors that constituted a synthetic variable, reducing the likelihood of a Type I error. This combination of factors overcame the limitations of any single factor in the evaluative process.

Although the methodology for this project was based on the work and theory of others, no single source served the goals of our study. Building on existing methods, we chose to modify some promising ideas to meet the needs of our work, rather than adapt our study to fit the molds and purposes of others. However, our strategies adhered to accepted standards and the procedural guidelines that support replication.

In analyzing the content of discussions, percent agreement for inter-rater reliability averaged 88% for coding six weekly transcripts, using Holsti's coefficient of reliability. Both the average and range (82% to 92%) of percent agreements were within acceptable limits for content analysis (Rourke et al., 2001a; 2001b), and data from discussion transcripts accounted for only one of three data sources (along with word count and patterns of interaction), as mentioned above.

The use of only two coders could be a threat to reliability, if the inter-rater reliability was based on a small portion of common or overlapping text. However, the two coders in this study separately coded all of the selected text. Coding disagreements could present another threat to reliability in the way that disagreements were settled between the two coders. In this case, coders used disagreements in training samples

as an opportunity to identify which categories were problematic and to clarify ambiguities in the coding scheme. As a result, disagreements on the discussion transcripts were mutually negotiated based on the revised coding schemes.

■ Implications for a Method to Gauge Interaction

This study provided a framework to gauge the level of interaction of coaches from diverse settings and geographic areas. By adapting more complex methods to fit our needs and using a combination of indicators, we established the usability of a simplified, formative evaluation strategy that will provide a basis of comparison for cycles of project work in the future.

The methodology might also be useful in other settings that serve distance learners. For example, higher education instructors or corporate trainers might use it to evaluate, refine, and improve the design or facilitation of online courses.

The methodology itself has potential for further development and refinement. Possibilities include the use of a common scale for the three dimensions of interaction and an “interaction index” that will facilitate comparisons across the cycles of each project. Used at formative stages of a discussion, an interaction index might prompt customized changes in discussion structure to meet the needs of participants. This might prove especially helpful in improving the professional learning experience for a diverse group of participants from a variety of school settings.

■ Implications for Design Changes

Evidence points to an increase in peer-to-peer interaction and discussion quality in the third seminar where we implemented the structural change of designated discussion leaders for examining the case studies. This study offered additional insights into the types of features (such as type and design of activities, duration, and mechanisms that foster collective participation) that may be adapted and used to refine the structure of online professional development. Further study could investigate these and other features.

■ Importance

This study provided a framework to gauge the level of interaction of mathematics coaches from diverse settings and established a basis of comparison for future seminars (including seminars for mathematics teachers), which is useful for modifying discussion strategies in order to improve the quality of professional

development. For our purposes, the results will inform our effort to improve the level of engagement and the quality of professional development to educators with limited access to curriculum support. This is important because mathematics coaches and teachers, especially those from schools with limited resources and in geographically isolated areas, need access to high-quality professional development. In addition, these results highlight the relevance of the concept of distributed participation from many schools, versus a single school, as an encouraging, open environment that promotes innovative solutions and new perspectives for underserved populations.

■ Application for Districts

As the literature and feedback from seminar participants shows, coaching is a multi-faceted role requiring skills in facilitating professional development both in one-to-one classroom and group situations. Coaches are often tapped for a wider range of activities such as curriculum training, facilitating grade-level or school-wide meetings, and working with district-level committees and policymakers. Coaching requires a range of competencies including: knowledge of mathematical content and instructional practices, clinical skills focused on individual teacher practice, and the ability to build capacity and support for reform at school and district levels. As school districts invest in coaching as a means for improving teacher practice in content areas such as mathematics, coaches themselves need the type of resources and professional learning that online communities can provide.

The Investigations seminars provided unique access that is often unavailable to coaches, enabling participants to interact with peers from different contexts and to engage in reflective analysis of their own practices. When undertaken in this way, an online seminar fosters the development of distributed competence by providing external resources that allow practitioners to examine their local practice through comparison with those in other settings. Furthermore, by expanding the role for discussion leaders, the Investigations seminars provided an authentic task for participants both in analyzing key concepts from the case studies and framing questions about the coaching situation for others to consider. Such authentic tasks could extend coaches' capabilities in their on-site professional development roles.

Our experience to date with the design and evaluation of the online seminars strongly suggests that they can be powerful tools for professional learning, meeting the needs of local practice, while connecting educators from various schools or districts. Although the Investigations seminars met the specific needs of elementary mathematics coaches using the curriculum, more systematic study could examine the types of professional development needed by those undertaking the coaching role in various contexts, such as coaching at different grade levels, coaching for a variety of content areas, or coaching in a single district or state.

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APPENDIX

The following discussion excerpts are examples of typical thematic units that were coded under each category. The categories are aligned to Bloom's taxonomy and are on a continuum that (1) ranges from concrete/simple to abstract/complex concepts and (2) requires lower to higher order thinking skills.

ABSTRACT ↑

THEORY: Postings are theory-based and may include mutual negotiations with other participants to clarify understanding. References to theory-based readings demonstrate higher levels of reasoning and may inspire constructive discussion.

Alignment With Taxonomy: Assesses the value of concepts; relates to relevant theories.

Examples:

- "According to *Helping Children Learn Mathematics* by Reys et al., the nature of place value rests on two values...Where I think we fall down in our thinking is that we use place value as a means to understand the algorithm for addition, subtraction, multiplication and division. We don't take the time to develop an understanding of what place value really is and the effect it can have on our lives...(Uses the expandable memory of personal computers as an example of place value in base 2.)"
- "By using an outside piece of information like *Carpenter's Children's Mathematics Cognitively Guided Instruction*, the coach could show Bob the different types of solutions his students used."
- "Could the class work as a whole be broken down into two or three categories of students and then those understandings and/or confusions be brought to the fore next—through an effective series of mini-lessons, such as Fosnot suggests with number strings?"

NEW POINT: Postings build on previous discussion by questioning for more detail or generating new ideas for further discussion.

Alignment With Taxonomy: Solves problems; introduces new perspectives; extends original concepts; synthesizes information to create new meaning.

Examples:

- "To paint a picture of the ideal mathematics teacher coach I need to use two brushes. One brush to show skills such as deep mathematics understanding, effective communications skills, classroom experience, and an understanding of the pedagogy of mathematics teaching. The other brush reveals the art of building trust and the wisdom to really see and hear beyond what's happening in the classroom."
- "I have found showing student work on overheads to be effective in yet another way... The students have to puzzle, just the way we do as teachers, to make sense of their classmate's work. The classroom community becomes teachers and learners teaching and learning together. What could be better?"
- "If all strategies are given equal credence by the teacher, the students might emulate the wrong ones. What if Claire is a leader in the class and other children decide to use her method because she is popular and it looks easy even though it probably won't work...?"

EXPERIENCE: Postings reflect personal or professional experiences and may build on previous discussion.

Alignment With Taxonomy: Interprets knowledge through experience; translates topics to new contexts.

Examples:

- “In my own experience, I have found that teachers have difficulty framing questions or situations that will help children to use strategies or think in a different way—perhaps because we are so used to showing kids how to do it.”
- “These questions relate to my current position. My role has never been clearly defined ahead of time and I feel that is why I did not have the focus that I would have liked.”
- “I facilitate a study group around ‘leadership’ at the college. Our teachers were asked to create their concept of ‘leadership’...What they created was both astonishing and profound...I will borrow from one of my students...She painted a picture of snow geese flying in ‘V’ formation...As the lead bird tires and feels confident in the other birds to carry on, it drops back letting another bird take the lead...What a perfect metaphor for what we (those of us as coaches or lead teachers) should be striving to do.”

COMMENT: General remarks may paraphrase, reflect, or interpret previous material, but do not add new information or ideas. They may also include independent opinions.

Alignment With Taxonomy: Does not substantiate comments; shows a working knowledge of topic; does not connect to larger concepts.

Examples:

- “I, too, believe that it was significant that the coach used student work to focus the dialog with the teacher—that took the focus off the teacher and freed her from evaluation.”
- “I totally disagreed with you in your first posting, but totally agreed with you in your second posting...And I think you give a great answer to your own question.”
- “I think that coaching is a balance among a variety of skills, knowledge and intuition. The role is multifaceted and includes modeling, questioning, supporting...”

CONCRETE ↓

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