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Online Discussion as a Mechanism of Conceptual Change Among Mathematics and Science Teachers

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Abstract

This study examines the extent to which conceptual change is stimulated and achieved through online discussion in the context of an online graduate course. Transcripts of discussions among 15 graduate students studying assessment issues in mathematics and science education were analyzed using an interaction analysis model developed to assess knowledge construction and conceptual change in the context of an online debate. Although evidence of authentic conceptual change was limited, significant cognitive activity supporting conceptual change was identified. We offer observations about course characteristics that contributed to conceptual change, discuss the limitations of applying an existing content analysis model to a new context, and suggest further research focusing on mathematical discourse and scientific inquiry in the online environment.

Résumé

Cette étude examine jusqu'à quel point un changement conceptuel est stimulé et réalisé à travers une discussion en ligne dans le contexte d'un cours de deuxième cycle en ligne. Les transcriptions des discussions entre quinze étudiants gradués étudiant l'évaluation en mathématique et en sciences de l'éducation ont été analysées grâce à un modèle d'analyse de l'interaction développé pour mesurer la construction de connaissance et le changement conceptuel dans le contexte d'un débat en ligne. Malgré le fait que les preuves qu'un changement conceptuel authentique se soit produit sont limitées, une activité cognitive significative supportant le changement conceptuel a été identifiée. Des observations sont présentées sur les caractéristiques d'un cours contribuant au changement conceptuel, de même qu'une discussion sur les limites de l'application d'un modèle d'analyse de contenu dans un nouveau contexte. Des suggestions sont faites pour de nouvelles études centrées sur le discours en mathématique et en recherche scientifique dans les environnements en ligne.

Introduction

Distance learning modes, particularly computer-mediated communication (CMC), have opened new pathways to higher-level thinking via discussion, reflection, and negotiated meaning. CMC has also enhanced the ability to study not only the outcomes of interaction, but the process of interaction itself as the vehicle by which larger purposes are achieved (Wells, 1999). Analysis of discourse—in this case, online discussion—lends itself not only to assessing whether an individual has achieved the end of acquiring new knowledge, but provides an avenue for studying the process of acquiring that knowledge—the *means* by which new knowledge is achieved—as a phenomenon in itself. This article investigates the potential for promoting and supporting conceptual change via online discussion in the context of graduate-level coursework among mathematics and science educators.

The proliferation of various forms of online interaction in educational settings not only brings a new perspective to the study of conceptual change and the process of knowledge construction, but has augmented the techniques available for data collection and analysis in this arena. CMC supplies a wealth of data in the form of detailed, electronically archived transcripts that allow researchers to "observe" online interaction in the same environment in which participants experienced it. The flexible structure of online discussion also supports rich and diverse forms of analysis: for example, a variety of topical threads can be followed in a single discussion; several discussions can be compared; or a series of discussions can be analyzed to track changes over time.

The effectiveness of CMC as an educational tool has received attention in research in terms of quantifiable outcomes such as patterns of interaction and degree of participant satisfaction (Fahy, 2003; Kanuka & Anderson, 1998; Stacey, 1999). However, answers to questions about the quality, content, and cognitive level of online discussion are more elusive. In an extensive review of research on distance learning in education settings in the 1990s, Phipps and Merisotis (1999) identified only 40 studies based on original research (dedicated to explaining or predicting phenomena related to distance learning) from among several hundred articles examined. In their content analysis of the *Journal of Distance Education* from 1986 through 2001, Rourke and Szabo (2002) found that most published articles were descriptive in nature, with a very small percentage based on theoretical research. The results of this study add to the empirical research base regarding quality of discussion and evidence of conceptual change in online discourse.

Purpose

This study addresses the question, To what extent is there evidence of conceptual change through online discussion among graduate students in a CMC course environment? Of related interest is whether the course structure provides adequate scaffolding to nurture conceptual change. To explore these questions, we searched for evidence of conceptual change among students studying assessment issues in mathematics and science education in a fully asynchronous online graduate course. We applied methods of content analysis to individual messages, but expanded this with a more global analysis of overall context and the cumulative effect of message sequences.

In their work on critical thinking, Garrison, Anderson, and Archer (2001) identify cognitive activity as "both a process and an outcome.... the acquisition of deep and meaningful understanding as well as content-specific critical inquiry abilities, skills, and dispositions" (p. 8). In a similar manner, we interpret conceptual change as both an outcome (evidenced by deeper understanding and new knowledge of the topic at hand—in this case, assessment) and as a process (evidenced by increasingly sophisticated levels of cognitive activity, efforts at synthesis and analysis, and other processes supportive of conceptual change). We incorporate both these perspectives into our discussion of results.

Data analysis was conducted using Gunawardena, Lowe, and Anderson's (1997) interaction analysis model, which was developed to identify and categorize levels of conceptual change and knowledge construction in the context of a six-day international online debate. This study expands Gunawardena et al.'s exploration of knowledge construction and conceptual change and applies their model for analyzing online discourse to a context different than that used in the original research. In our discussion of results we address the feasibility and usefulness of applying this model to the analysis of conceptual change in a different setting.

Research Framework

In considering how best to approach analysis of conceptual change in the CMC environment, we (one the course instructor, one a participant in the online course) explored the literature on constructivism and conceptual change. Although constructivists use many lenses to view the conceptual change process, two consistent tenets of the theory hold that learners are active builders of their own knowledge and that there is a need for "connecting the new knowledge to be acquired with the existing knowledge that students have" (Limon, 2001, p. 358). Researchers have studied conceptual change in terms of processes that occur in the individual as he or she interacts with new ideas (Piaget, 1975; Strike & Posner, 1992); others have examined aspects of conceptual change in the context of social interaction (Limon; Vygotsky, 1978).

Posner, Strike, Hewson, and Gertzog (1982) view conceptual change in terms of conditions and effects that occur in the individual. They adopt the language of Piaget in defining a two-phase process of change that includes assimilation, where students use the concepts they have already mastered to organize and make sense of new phenomena, and accommodation, brought on when "current concepts are inadequate.… Then the student must replace or reorganize his central concepts" (p. 12). Dole and Sinatra (1998) identify factors that affect conceptual change, including personal relevance for the individual, adequate background knowledge, sufficient cognitive ability, and comprehensible information. They further state that change in beliefs can occur on an individual level when students engage in a thoughtful, effortful processing of arguments. Limon (2001) cites additional factors that contribute to conceptual change, including "motivation, learning strategies, epistemological beliefs, attitudes … the teacher … and social factors, such as the role of peers" (p. 365). Such factors can be observed in the online setting if participants are encouraged to reflect in writing on their own reactions and thought processes and to respond thoughtfully to the comments of others.

Gunawardena et al. (1997) note, "It is important to recognize the interdependence of both the individual and the social construction of knowledge" (p. 409). Social interaction and the development of a community of learners can be influential factors as well, as documented by the growing knowledge base on the value of online learning communities (Conrad, 2002; Palloff & Pratt, 1999; Stacey, 1999). This influence may vary with setting; Conrad suggests that the unique characteristics of the online classroom, where community is "constructed and maintained as a necessary tool for the completion of tasks" (p. 11), may produce a more pragmatic, functional version of community than in other online scenarios. What, then, are pragmatic and functional ways instruction can be designed to promote conceptual change in the online classroom?

Limon (2001) groups instructional strategies that promote conceptual change into three categories: developing cognitive conflict, applying analogies, and facilitating "cooperative and shared learning to promote collective discussion of ideas" (p. 358). These cognitive tools can be identified in online discussion. Another means for assessing the process of conceptual change in the online environment is observing the existence of *cognitive presence* in discourse. Garrison et al. (2001) define cognitive presence as "the extent to which learners are able to construct and confirm meaning through sustained reflection and discourse in a critical community of inquiry" (p. 11) and note that "cognitive presence focuses on higher-order thinking processes as opposed to specific individual learning outcomes" (p. 12).

The synthesis of these perspectives guided our approach to this research. Data for the study were gathered from an online course that was designed to encourage shared learning and facilitate collective discussion. The course units and discussions chosen for analysis were those most likely to motivate students to reflect on and apply their own knowledge and experience. The content analysis instrument we chose embeds references to cognitive conflict, analogous thinking, reflection, higher-order cognitive processes, and conceptual change in defining its five phases of knowledge construction. Beyond content analysis, we hoped that our personal involvement in the course, coupled with a qualitative review of both individual messages and sequences of messages, might bring to light more subtle evidence of conceptual change.

Method

Setting

The online course in this study was sponsored by the Center for Learning and Teaching in the West (CLTW), a consortium of K-16 institutions in Montana, northern Colorado, and Portland, Oregon, funded by the National Science Foundation's Mathematics and Science Partnership program. One aspect of the partnership's mission is to produce future leaders in higher education through a doctoral fellowship program in mathematics and science education. The core curriculum of this program is derived from a set of 15 online course offerings grouped thematically into five triads. Each triad is sponsored by one of the five campuses involved in CLTW using Web-based course software such as WebCT® or Blackboard®. Doctoral fellows at any participating campus enroll in these courses as they continue their regular research, professional development, and teaching activities. This study examines one of the CLTW online courses sponsored by Montana State University in the Curriculum-Assessment-Evaluation triad. The first course in the series, "Curriculum Design: The Case of Mathematics and Science," was first offered in fall 2002. The course analyzed in this study, "Models of Assessment in Mathematics and Science," followed in spring 2003.

As is typical in CLTW distance learning, the Assessment course in this study relied heavily on facilitated participant discussion. The course was divided into units lasting from two to three weeks and included completion of readings and activities, both scaffolded and unstructured discussions, and sharing of research in online forums. A typical unit discussion generated 150 to 200 discussion messages from the 15 participants. In total the various discussions in the Assessment course generated over 2,000 discussion messages during the spring 2003 semester.

Collins and Berge (1996) suggest that online instructional roles fall into four categories: pedagogical, managerial, social, and technical. The course instructor fulfilled all these responsibilities in designing course content, building the course shell, introducing students to the software platform and to each other, and initiating the course. She also laid the foundation for each subsequent unit by providing an overview of the unit topic; laying out guidelines for conducting activities and summarizing the assigned readings (book chapters, journal articles, and online documents); and introducing questions to begin each discussion. The instructor, a university faculty member with several semesters' experience in designing and instructing online courses for graduate students, sought to create an environment where "members question one another, demand reasons for beliefs, and point out consequences of each other's ideas-thus creating a self-judging community" (Garrison et al., 2001, p. 12).

New discussions were opened for each unit. In the first two units, students were assigned to one of three discussion subgroups. Based on students' requests for larger groups, subsequent units included two discussion groups of seven or eight, each led by a student facilitator. Discussion groups were shuffled after every two units, and new group facilitators were assigned for each unit. The facilitators, most of them experienced educators, were given individual guidance in initiating, stimulating, monitoring, and summarizing the discussion for their particular unit. The instructor provided each facilitator with what Palloff and Pratt (1999) call "expansive questions" designed to promote "deep exploration of a topic and the development of critical thinking skills" (p. 199).

Stacey and Rice (2002) suggest that although it is the instructor's role to establish a secure environment for interaction, that environment can eventually be structured by the instructor but led by students. The instructor did have a presence in the unit discussions to comment, answer specific questions, and synthesize ideas; however, the student facilitators were also expected to develop these skills as part of their fellowship training. Besides modeling desirable facilitator traits, the instructor communicated with group leaders through individual e-mail, providing appropriate questions, suggesting lines of inquiry to pursue, and offering ideas to direct and redirect the discussion. In short, the instructor attempted to build in the group leaders the skills of facilitation and questioning needed to generate thoughtful, quality discussion.

At the end of each unit discussion, the facilitators completed a survey summarizing the key points raised as well as critiquing the quality of the discussion. In addition, discussion members were required to complete a self-evaluation of their level of participation at the end of each unit discussion. The four-point rubric asked students to reflect on their efforts to interact, if not on the depth of those interactions:

> Did I respond at least once to the questions/issues raised by my discussion leader? (1.0)
> Did I submit a second response raising an original question or exploring

an issue related to the readings and/or assignments for the week? (1.0)
Did I submit a response to at least two other members' messages? (1.0)?
Did I make a connection between course material and my classroom/school? (.5)
Did I get involved early in the first week, so others could respond to my messages? (.5)

When specific discussions were set up to support a unit activity, students were given guidelines both for presenting their activities and for responding to the presentations of others. These guidelines focused more on stimulating a give-and-take forum atmosphere than on deliberately coaching higher-level thinking.

Luebeck, a mathematics education faculty member, was the instructor for the assessment course; Bice, at the time a high school science teacher and CLTW doctoral fellow, participated as a student in the course. The Assessment course was designed and implemented according to CLTW standards and in collaboration with the designers of the curriculum and evaluation courses, with no research intent influencing any part of the process. Only after the course was completed, when we were studying the work of Gunawardena et al. (1997) and others regarding knowledge construction and conceptual change in a structured CMC environment, was the present study conceived and designed. We were intrigued by the notion of extending the investigations and findings of Gunawardena et al. to a new context: that of more collaborative interaction among relatively like-minded educators in an online graduate course.

Description of Participants

The 15 students in the Assessment course represented a wide variety of experiences and education-related professions, including secondary teachers, college instructors, professional developers, and doctoral students in content fields. Their familiarity with WebCT®) varied, but all had some degree of facility with distance learning and Web-based discussions. Twelve of the students had participated in the online CLTW curriculum course during the previous semester, which greatly leveled the playing field in terms of online experience. Nearly half the students were from Montana; others were located in Oregon, Arizona, New Mexico, Alaska, South Dakota, and Washington, DC. They worked in both urban and rural settings; some dealt directly with underserved populations (primarily Native American).

Selection of Instrument

To search for evidence of conceptual change in online discussion, we chose the method of content analysis defined as "a research technique for the objective, systematic, and quantitative description of the manifest content of communication" (Berelson, 1952, cited in Borg & Gall, 1989, p. 519). Relatively new to the field, we reviewed the literature on evaluation methodologies for computer conferencing and examined several existing scales and inventories. We chose the interaction analysis model developed by Gunawardena, Lowe, and Anderson (1997, referred to below as GLA) based on several criteria. First, the model, with its identification of five phases of knowledge construction (sharing ideas, encountering dissonance, negotiating meaning, and eventually reaching conceptual change through processes of synthesis and application), was well suited to content analysis. Second, the model was developed to measure quality rather than quantity of interaction to determine whether "individual participants change their understanding or create new personal constructions of knowledge" (Gunawardena et al., 1997, p. 399) through group interaction. Third, we believed that of the instruments we reviewed, GLA was most capable of detecting cognitive conflict, analogous thinking, reflection, and higher-order cognitive processes: aspects of the learning process that the literature suggests are supportive of conceptual change. Finally, the model suited our context of discussions among experienced educators. Garrison et al. (2001), who examined GLA in developing their own model of critical inquiry, note that such models are "more appropriate where applied knowledge is valued-particularly adult, continuing, and higher education" (p. 21). Key descriptors for the five levels identified in the GLA interaction analysis model are provided in Table 1.

Data Analysis

Due to the volume of messages generated in the Assessment course (over 2,000 total), we felt it necessary to limit the data to be analyzed. Kelly and Green (1998) differentiate between arguing a position and changing one's conceptions. With this in mind, we chose the three instructional units most likely to push students beyond simply sharing their findings or comparing (and retaining) their views: units that encouraged students to think deeply and invited varied interpretations of the subject matter. These include:

- Unit 2: Formative Assessment—Students explored standards-based approaches to formative assessment in mathematics and science, contrasted the purposes and applications of formative and summative assessment, and debated the usefulness of assessment as a learning tool.
- Unit 5: Equity and Quality—Students identified and debated issues of equity in relation to assessment, considered validity and reliability in standardized testing, and contrasted state- and

Table 1
Summary of GLA Interaction Analysis Model (Adapted from Gunawardena et al., 1997)

Level	*Identity*	*Description*
1	Sharing and comparing	Statement of observation/opinion Statement of agreement Corroborating examples Asking/answering questions Identification of a problem
2	Discovery and exploration of dissonance or inconsistency	Identifying/stating areas of disagreement or inconsistency Asking/answering clarifying questions Restating a position/advancing an argument
3	Negotiation of meaning/co-construction of knowledge	Negotiation/clarification of terms Identifying areas of agreement/overlap Proposal/negotiation of compromise Proposal of metaphors/analogies
4	Testing and modification of the proposed synthesis	Testing proposed synthesis Testing against existing cognitive schema/experience/contradictory evidence
5	Agreement and application of new meaning	Summarization Applications of new knowledge Metacognitive statements illustrating self-knowledge of conceptual change

national-level tests with classroom assessment in terms of appropriate and useful reporting.

- Unit 7: Assessment Utopia—Students investigated the alignment of local, state, and national assessments with standards for mathematics and science at similar levels, debated the potential roles and responsibilities of "stakeholders" (e.g., students, teachers, parents, policymakers), and investigated alternatives to traditional high-stakes testing.

The remaining units generated excellent debate-style discussions that challenged the thinking of participants, but offered less evidence of convergent thinking. Unit 1 was more didactic in tone, used to develop a common vocabulary in terms of mathematics and science standards, types of assessment strategies, and familiar assessment issues. Unit 3 examined the range and scope of external assessment practices designed for local, state, and national purposes and introduced students to commonly held positive and negative views and the position statements of national education organizations. In Unit 4 students conducted individual research on an assessment topic of personal interest and presented their findings in an online forum. Unit 6, again didactic, revisited the contrast between formative and summative assessment data and described data-driven school change models. Several other discussions (the *No Child Left Behind* Education Act, how home schooling affects high-stakes assessment) arose spontaneously and were pursued with vigor, but not subject to the same instructional design.

We examined complete transcripts from each of the three selected instructional units and coded all messages individually (a total of 484 messages posted by the 15 students and instructor). A full message was determined as the unit of analysis. Too often single sentences or phrases taken out of context must be scored at the lowest level of "sharing and comparing" information, even though the message as a whole represents a higher level of knowledge construction. Garrison et al. (2001) further note that submessage units are more difficult to identify between coders and can reduce reliability.

Before coding the research material, we practiced coding by applying the GLA model to archived discussions from the online CLTW curriculum course, as well as to transcripts of interactions among teachers in an online mentoring program. Each individual coder was free to assign separate scores to distinct submessages in a single posting, but reported only one summary code for each posting when comparing results. We adopted Garrison et al.'s (2001) method of arriving at a meaningful final code for each message: "Code down (i.e., to the earlier phase), if it is not clear which phase is reflected; and code up (i.e., to the later phase), if clear evidence of multiple phases is present" (p. 9). To test for interrater reliability, we first individually coded all messages from a subset of five students (n=220), achieving a reliability rating of Kappa=.52. We discussed differences in coding for individual messages until a final code was agreed on for all messages. Preserving the codes for the five initial subjects, we then returned to the data to code individually the remaining messages. A reliability value for all 484 messages was calculated at Kappa=.83. As before, disagreements in coding were resolved through mutual analysis: these were typically due to oversight and were quickly resolved on reviewing the message.

Although discussion transcripts provided by computer-mediated communication are an invaluable resource, we are compelled to point out some of the limitations of content analysis in this context. In the asynchronous environment, participants have time to process their reactions and reflect on new ideas before responding to prompts. Garrison et al. (2001) suggest that "Observers view only that subset of cognitive presence that the participants choose to make visible in the conference" (p. 13). Members of an online discussion may put forward only the final results of a complex cognitive process, leaving intermediate steps unexamined. Indeed, we may not even see final results if students keep their cognitive processes internal or reserve a summary of their learning for individual assignments (in the Assessment course these included reading syntheses, a research report, and a final state assessment project). However, these phenomena are reflective of studying cognitive activity in any setting. Even if one can only observe snapshots of the conceptual change process, the online record serves as a remarkable source of evidence.

Results and Discussion

Evidence of Conceptual Change

A total of 484 messages were coded using the interaction analysis model developed by Gunawardena et al. (1997). The total numbers of messages coded at each GLA phase are shown in Table 2. The findings indicate clear evidence of cognitive conflict and analogous thinking as identified in GLA Phases 2 and 3. Far fewer indicators of reflection, metacognitive activity, and higher-order cognitive processes were evident: these aspects of the conceptual change process generally occur in Phases 3-5. Only seven of 484 (roughly 1.5%) of the messages represented testing and modification of proposed synthesis (Phase 4) and/or agreement and application of new meaning (Phase 5). In addition, 43 messages (roughly 9%) revealed that participants were engaged in negotiating meaning and constructing knowledge (Phase 3).

Significance of Interaction

Although the quantitative results provide limited evidence of conceptual change in individual messages, from a qualitative perspective the transcripts reveal numerous instances in which interaction among learners precipitated negotiation of new meaning. Additional evidence of conceptual growth and change is apparent when messages are read in the context of their respective discussion threads. With its emphasis on disagreement and negotiation, the GLA instrument tends to overlook the cumulative effects of an exchange of multiple viewpoints and the sharing of ideas that

Table 2
Coding Results for Three Units in the CLTW Assessment Course

GLA Phase	*1 Sharing/ Comparing*	*2 Dissonance/ Inconsistency*	*3 Negotiation/ Construction*	*4 Testing/ Modification*	*5 Agreement/ Application*
Messages coded at each phase	290	144	43	6	1

build on each other rather than conflicting. Evidence of testing, modification, and synthesis by the group may not be recognizable in the coding of individual messages, but is present in the interactive whole that spans a complete discussion thread.

As an example, consider how the following discussion thread interweaves personal experience, reaction, and reflection on the path to conceptual change. In this series of excerpted statements, participants are discussing how a transitory student population affects assessment practices and outcomes. At the conclusion of this exchange about educating transient students, Student P offers a metacognitive statement about her changed way of thinking.

> *Student R (Facilitator):* How do we assess these kids that move in and out of our schools like a morning fog that burns off by noon? Is testing more often the answer?
>
> *Student D:* I have a suggestion for at least part of the problem.… Standards-based report cards in each subject area would provide a comprehensive picture.
>
> *Student P:* Student D's suggestion would be great assuming content standards were consistent across districts and across states … directed by the national standards … Why aren't we?
>
> *Student W:* I realize that education stems from local control, and I agree, but … In my other life as a plumber, we don't reinvent the wheel each job. We have a basic framework in the plumbing code.
> *(Six messages omitted)*
>
> *Student M:* A checklist of what had been covered up to that point in the year might do the new teacher a lot of good.
>
> *Student R (Facilitator):* I like this check sheet idea.… Where he/she is in the scope and sequence of the curriculum might be a better approach than an exit or entrance exam.… How we determine this is the challenge.
>
> *Student W:* What if kids had to spend a day taking entrance exams whenever they moved to a new school …? Would they wish to move a lot? What if the parents had to spend a day getting a child all set up in a new school? Would they wish to move a lot?
>
> *Student P:* I don't know that parents "want to move a lot." I really believe that in most cases it is a necessity.… At least that is what I've seen in the communities in which I have taught. However, I really like the idea of entry testing.… it would make parents more aware of the impact that changing schools might have on their children.

> *Student D:* My students tell me plenty of reasons why they switch schools and they do it regularly.… If the student is having a hard time at school, scholastically, not being played on the sports team, fights with others, bad influences … pregnancy, poverty … the list goes on and on.… Most of these moves are within a 100-mile radius, but if there is a willing relative farther away they may make that move as well.

> *Student W:* To me, the child's education and continuity of education is important, even if that means parents putting some plans on hold.… Most of my midyear moves bring an assortment of baggage with them.

> *Student P:* Student D paints a picture of school switches and changes I have not experienced. Given this information, I can imagine that it is and would be frustrating to have to deal with such frequent and seemingly senseless changes from one school to another. Thanks … it helps me to relate.

There is considerable evidence of harbingers of conceptual change such as cognitive conflict stimulated by the interactive process of negotiating contrasting (and often conflicting) perspectives, as in the following excerpt where two students exchange views about the nature of standards-based instruction:

> *Student Facilitator:* Standards-based teaching/learning sounds a lot like mastery learning. Do you think so? I have had [an awful] experience with mastery learning.

> *Student D:* I'd have to agree with you. Sometimes it might be better to leave a subject for a while till your mind is better ready to handle it.

> *Student S:* I think standards-based is a lot different than mastery learning. I do think there needs to be a set of standards that we as a profession agree is our obligation to teach. If not, we would be all over the place.… [National Council of Teachers of Mathematics] math standards are not mastery learning at all—they inform teachers about the whats (and even some of the hows) to teaching math.

> *Student D:* To take the alternate point of view, how is becoming proficient in fractions any different than mastering them? … The only difference is we don't require complete mastery before going on to the next topic.

Finally, use of analogies is evident throughout the three course units as in the plumbing analogy given above. Another student clarifies her point by likening curriculum standards to standards for industry:

> *Student D:* Maybe we need to think of [education] as a business. Because we are not trying to attract "clients," we often just go our own way.… But

> most of the industrialized world uses national, even international, standards.… How awful would it be to buy a car in Montana, then move to Oregon, and find that nobody there knew how to work on it!

Increased Cognitive Activity Over Time

A comparison of coding results from the three instructional units in the Assessment course reveals that overall, participants' higher-level cognitive activity (as measured by GLA) increased over time (see Figure 1). Although we must interpret this result with caution, it suggests that as participants became more familiar with course procedures, their fellow students, and the subject matter, they were able to interact at higher phases in the GLA model. It is also noteworthy that the highest levels of cognitive activity (messages coded at Phases 4 and 5) occurred in the Unit 5 discussion about diversity and equity issues in standardized assessments. This was an area where students' prior knowledge was particularly challenged both by reading scholarly articles and by assimilating the strongly held views and personal experiences of others. At times a single discussion prompt generated 30 or more responses as arguments were advanced and new meanings were negotiated and tested.

Conceptual Change and Course Characteristics

We offer three observations specific to this study and the Assessment course that speak to the potential of online learning to support and encourage conceptual change. First, our results suggest that the geographic and experiential diversity of this group of online learners contributed to the development of new knowledge. Collectively the participants began the Assessment course with an awareness of educational policy in seven states, instructional expertise in mathematics and science grades 8-14, and

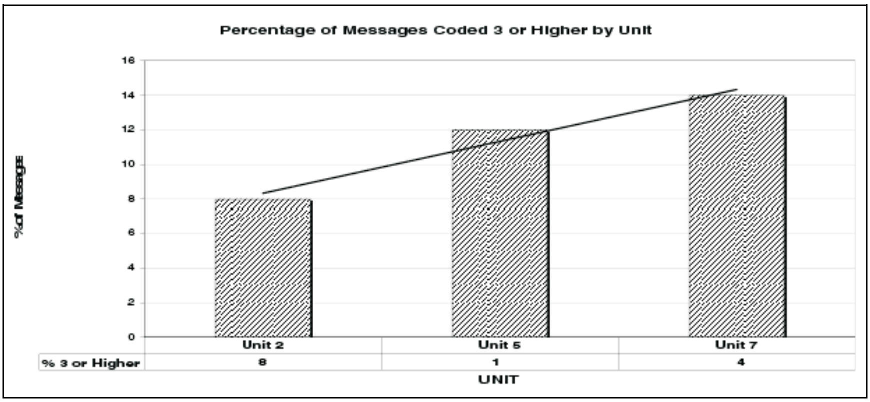

Figure 1. Percentage of messages coded at Phase 3 or higher across three Assessment course units.

a wide range of perspectives on assessment based on personal experience. Discussions and forum-style sharing sessions were naturally enhanced by the multiplicity of examples, vignettes, and comparisons introduced by the participants. Two (distinct) examples are given below.

> *Example 1: Student W.* As I've been in reservation schools over this past semester, I can't help but watch the results of students in poverty. It certainly overshadows the culture. I watched poverty in inner city Harrisburg [PA] and I saw much the same results on students. Poverty seems to make people give up, not care, not try, not have hope.

> *Example 2: Student D (a teacher of Native American students).* The answers I get on tests are much more European than the ones I get when I ask a question in class or hear two students talking amongst themselves.... What is so fun to listen to is a conversation in Crow. The language is very descriptive, each word describes what they see.

Second, analysis of these discussions supports the notion that the opportunity for teachers to engage in online learning concurrently with their own teaching enhances social interaction and supports conceptual change. Berge (2002) makes it clear that situated learning, or learning in context, is "critical for determining meaning" (p. 183). Many of the students were actively engaged in curriculum planning and assessment activities while taking the Assessment course and were able to provide real-time commentary and comparisons. They found their viewpoints and beliefs challenged not only by readings and research, but by peers who were experiencing a different reality at that very moment in their state, district, and classroom.

Finally, this study demonstrates the importance of deliberate "cognitive coaching" if the desired outcome is higher-level thinking, negotiation of meaning, and eventual conceptual change. Vrasidas and McIsaac (1999) found that increased structure led to more dialogue and interaction, but our results suggest that structure is not enough to influence higher-level thinking. In this online course the audience comprised self-motivated educators and scientists, discussion facilitators were provided with thought-provoking questions, and students were given guidelines for their participation and required to evaluate their own interactions; however, significant evidence of conceptual change did not appear. Knowlton (2003) warns us that "Critical thinking is abstract, and students may not know how to operationalize and apply it in their discussion contributions" (p. 35). Despite the behind-the-scenes support they received, graduate students in the Assessment course discussions were generally not successful in elevating the discussion to the highest levels of the GLA model.

Adaptability of the Instrument

The results of this study did not differ substantially from the findings of Gunawardena et al. (1997) in terms of Phase 4 and 5 messages. However, the results at the opposite end of the scale are significantly different. There were far fewer messages at Phase 1 among the 15 students participating in the Assessment course (61% at Phase 1) than for the participants in the online debate studied by Gunawardena et al. (93% at Phase 1). Participants in the Assessment course appeared to move beyond the sharing-and-comparing stage more easily than those involved in the international debate. This outcome was not unexpected given that in the global debate context, relative strangers were expected to adhere to and defend a specific assigned point of view. By contrast, the Assessment course invited participants with similar backgrounds and some degree of familiarity to exchange views over a much longer period. We recognize that development of the GLA model was grounded in a particular context and do not suggest that this is sufficient to identify cognitive activity and conceptual change in all other online settings. However, the GLA model was useful in quantifying the cognitive activity of the online learners in this study.

Overall, although the interaction analysis model designed by Gunawardena et al. (1997) is a useful starting point, we found that the debate context used to develop the model severely limits its application to other settings. Development of the GLA model assumed—in fact contrived—a contentious context with the goal of resolving opposing viewpoints. An exploration of issues in a cohort of graduate students is not likely to produce such a scenario. In this study difficulties arose with clearly differentiating Phases 2 and 3 messages because indicators for those phases in the GLA model imply the existence of disagreement and a need to resolve conflict. In fact some of the low coding scores we report may be the result of our hesitancy to assign higher values to messages that may have demonstrated movement toward conceptual change, but lacked features that matched GLA indicators referring to dissonance, disagreement, and a need to negotiate opposing views. A model that moves away from learning through rational argument ("I will convince you") to a more fluid process of learning through interaction ("Let's pursue this together") would be more suitable to the graduate student experience.

Conclusion

The results of this study suggest that the building blocks of conceptual change, and conceptual change itself, can be identified through the examination of online discussion among adult learners in a graduate course. However, there is limited evidence to indicate that interactive discussion in the CLTW Assessment course resulted in conceptual change and new understandings for individual students. This may have been due in part to the limited abilities of student facilitators to push students to higher cognitive levels. We contend that it is also due in part to the inability of the data analysis model to interpret adequately knowledge construction in the graduate course context.

Knowlton (2003) asks whether evaluation systems for online discussion can transcend disciplinary lines. The pedagogical, social, managerial, and technical components of online instruction identified by Collins and Berge (1996) do not directly address how an instructor delivers specific content or how it is received. However, Conrad (2004) found that new online instructors were most concerned about successfully delivering content. Can an instrument be developed to determine effectively whether conceptual change occurs in the realm of teaching and learning mathematics and science?

White (2002) observes that conceptual change may be viewed as discipline- or even topic-specific. The importance of discourse and communication in supporting the learning of mathematics and science is well documented by the national standards for both disciplines and in related research (National Council of Teachers of Mathematics, 2000; National Science Teachers' Association, 1996). Our next steps are to add to this work by investigating how the online arena contributes to teaching and learning science and mathematics. In particular, we are encouraged to pursue the development of a content analysis model that specifically attends to the construction of mathematics and science content knowledge.

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