# The Sequential Analysis of Individual versus Collaborative Writing Processes in Wikis

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**Abstract.** When students engage in collaborative processes like summarizing, questioning, and clarifying, students produce higher quality text. Yet, research shows that groups tend to choose approaches so that members work more on an individual than collaborative basis. Is this also the case when students use wikis? How and to what extent do students collaborate? How can collaboration be measured and operationally defined? This case study illustrates a method for coding behaviors recorded in wiki page revision histories and using sequential analysis to build process models and transitional state diagrams that quantitatively and graphically identify patterns in the action-sequences students performed in a Wiki. This study presents some of the initial findings, implications for future research and instructional applications, potential strengths and limitations of the described method, and directions for further development and refinement of the method.

## Introduction

When learners work collaboratively to summarize, question, and clarify, students achieve significant improvements in their ability to comprehend and write higher quality text (Palinscar & Brown, 1984; Scardamalia & Bereiter, 1996). However, Ede & Lunsford (1990) found that collaborative writing groups most often use strategies 1, 2 and 3 (Table 1) in which group members primarily work individually (sequentially or in parallel) rather than collaboratively (or reciprocally). Is this also the case when Wikis are used to facilitate collaborative writing?

**Table 1**. Ede & Lunsford (1990) coordination strategies

| Writing Coordination Strategies |
|---|
| 1. The group plans and outlines the task, then each writer prepares his/her part and the group compiles the individual parts, and revises the whole document as needed |
| 2. The group plans and outlines the writing task, then one member prepares a draft, the group edits and revises the draft. |
| 3. One member of the group plans and writes a draft, the group revises the draft. |
| 4. One person plans and writes the draft, then one or more members revises the draft without consulting the original authors |
| 5. The group plans and writes the draft, one or more members revise the draft without consulting the original authors. |
| 6. One person assigns the tasks, each member completes the individual task, one person compiles and revises the document |
| 7. One dictates, another transcribes and edits |

A number of reasons might explain why groups tend to write individually rather than collaboratively: (a) parallel approaches require less work and group communication compared to reciprocal approaches that require shared planning, writing, and editing; (b) students are reluctant to edit other students' writing (Ebner, Zechner, Holzinger 2006) for fear of causing controversy; (c) students are not presented with sufficient protocols on how to edit group documents in ways

that effectively manage conflicts (Slagter, Efimova, 2007) and problems with merging multiple versions (Sharples, 1999 p. 172); and (d) insufficient motivation to engage in collaborative editing (Zeinstejer, 2008).

At this time, little is understood about how and to what extent these and other factors affect the way groups collaborate on writing tasks (including the quality of the group product) because the methods used in prior research do not provide adequate means to model and describe with precision the actual sequences of actions students perform to achieve the desired outcome. As a result, the purpose of this study was to develop and test a method for coding writing behaviors logged in the revision histories of a Wiki and to sequentially analyze and model collaborative writing processes observed in a Wiki by addressing the following questions:

1. How do we code the student actions recorded in wiki page revision histories?
2. How can we use sequential analysis to identify sequential patterns in the actions students perform on the Wiki?
3. Do patterns exist in the sequence of actions performed by learners writing individually versus collaboratively, and if so, how to these patterns differ?
4. Are the writing processes identified with sequential analysis consistent with prior research findings on how students use Wikis?

## Theoretical Framework

The Dialogic theory of language (Bakhtin, 1981; Koschmann, 1999) assumes that: a) meaning is re-negotiated and re-constructed as a direct result of cognitive conflict produced in social interactions, and that conflict is the primary force that drives the processes of critical inquiry; and b) conflict is produced not by examining an utterance (or action) by itself, but by examining the relationship between utterances (actions and reactions). Support for this theory can be found in the research that shows that the need to explain, justify, and understand is felt and acted upon only when conflicts or errors are brought to attention (Johnson & Johnson, 1992; Wiley & Voss, 1999; Baker, 1999). Based on these assumptions, this study examined for example how often and how likely a newly added paragraph submitted by one student was edited versus deleted by the *same* student, or edited versus deleted by a student peer because these actions serve as potential indicators of disagreement and conflict. The process models identified in this study serve to provide insights into the actions that trigger further changes in the text that reflect deeper inquiry and understanding.

# Method

## Design

A naturalistic case study research design was used to identify individual and collaborative writing behaviors observed in a wiki, and to identify differences in the sequential patterns of writing behaviors exhibited in individual and collaborative processes.

## Participants

The participants were eight graduate students (3 male, 5 female) in a graduate-level online course on computer-supported collaborative learning taught at a major southeastern university.

## Instructional treatment

Students were assigned three activities (Figure 1) to describe methods to establish positive interdependence (week 4), individual accountability (week 5), and social team work skills (week

6). Each week, each student selected two unique readings from a pool of articles. Students used a designated wiki to describe any methods revealed in the readings, describe its potential impact, and identify issues in implementation. In each of these weekly assignments, students were required to submit a minimum of 6 contributions to each wiki to receive 10 participation points for each activity. No criteria were given to students on the exact requirements for each contribution except that each had to be submitted in separate document versions in the wiki.

Coding wiki edits by paragraph

In this particular case study, only the first wiki assignment on the topic of positive interdependence was coded and analyzed. To classify actions performed on each paragraph produced in the wiki, data in the wiki history page (Figure 2) was used to identify the student that performed each change and the changes the student performed on a given paragraphs and/or topic heading (Figure 3) in relation to the previous version. Added text was identified in green blocks. Deleted text was identified in red blocks. A qualitative analysis of the history pages produced six action categories (defined and illustrated in Table 2) – add topic heading, add paragraph, add text to existing paragraph, minor edits to paragraph, and major edits to paragraph. When a student made changes to another student's paragraph, the assigned code was tagged with a 'o' (e.g., EDITo). As a result, a total of twelve categories were added to the coding scheme.

To code all changes made to specific paragraph from the time the assignment started and ended, the coder's visual attention was focused solely on the set of paragraphs posted under a specific topic/heading while passing through all 68 history pages from the start to end. This process was repeated for each of the 13 total topics posted to the Wiki. All changes performed on *each* paragraph (including the name of the author that performed the changes) were recorded in chronological order. The experimenter coded the paragraphs posted under the first three topics headings on two different passes and the codes between the two passes was 83.3% in agreement, Cohen's Kappa = .932.

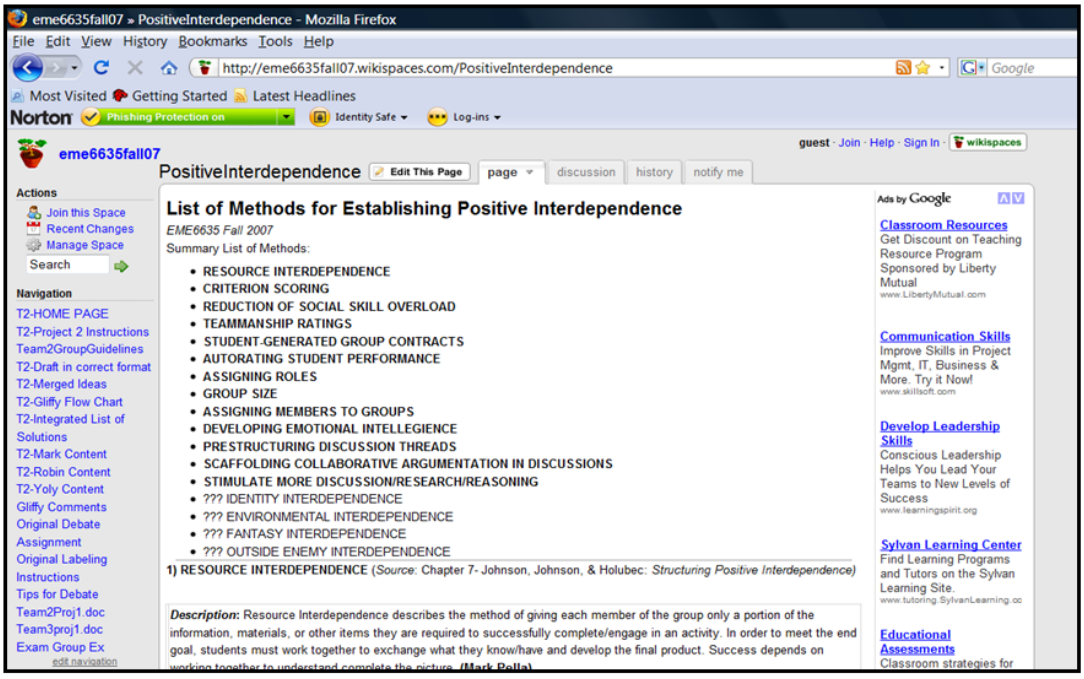



**Figure 1**. Wiki produced in week 4 on techniques used to establish positive interdependence

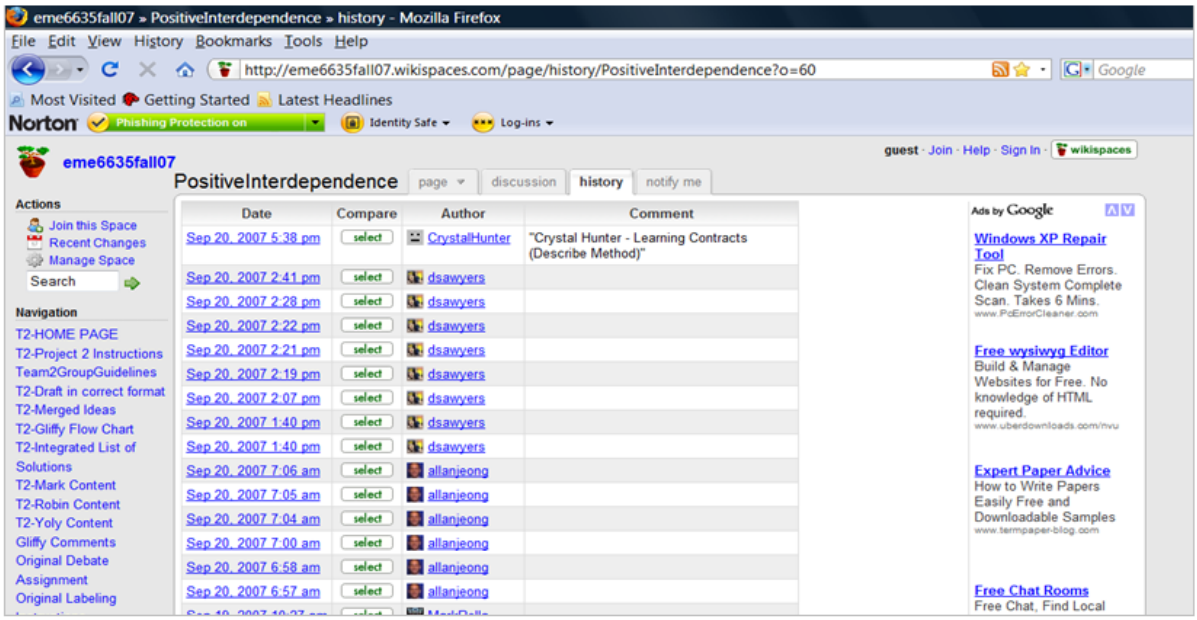



**Figure 2**. Wiki history page used to select and compare two versions

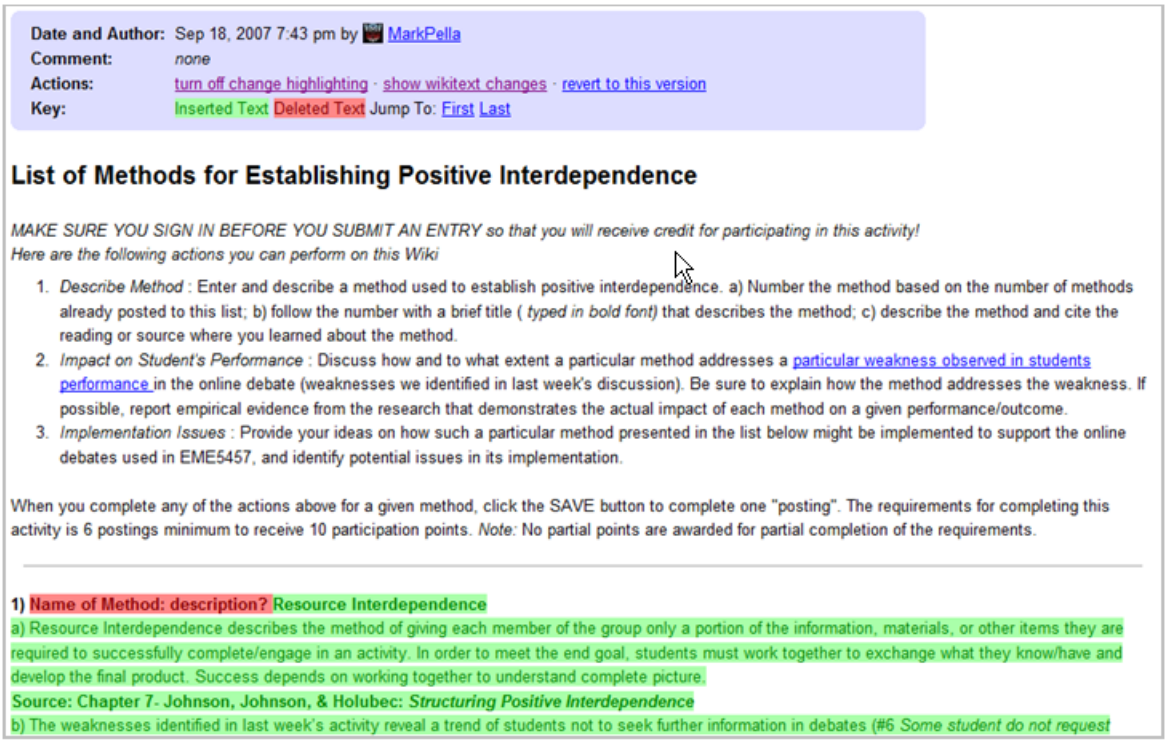
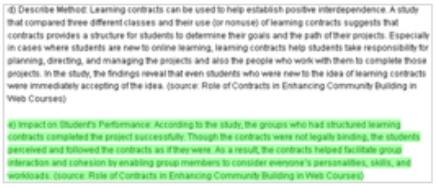
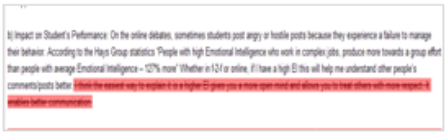


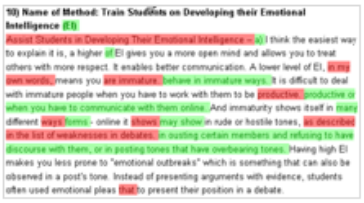

**Figure 3**. Inserted and deleted text highlighted in green and red color

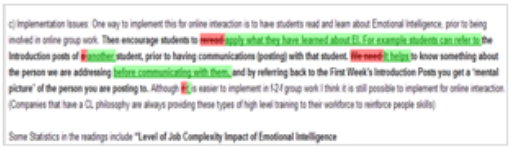
**Table 2**. Rules for assigning codes

| Code | Description |
|---|---|
| tADD | New topic heading |
| pADD | Add new paragraph below a heading |
| DEL | Red text deleted |
| EDIT | Red text displayed adjacent to green text |
| mEDIT | Green text, or red and green blocks in close proximity indicative of minor formatting e.g. addition of names, corrections in spelling, grammar and/or punctuation |


*Note*. If action is performed on a paragraph/heading by a student *other* than the original author of the paragraph/heading, the tag 'o' was added and appended to the code (e.g., EDITo)

Analyzing the code sequences

For each paragraph/heading, codes were sequentially entered into one column in an Excel spreadsheet (Figure 4). In column two, a sequence number was entered for each code ranging from 1 to x (the total number of changes performed on the paragraph/heading). New topic heading (tADD) was assigned the number 1. Paragraphs added under each heading (pADD) were assigned a 2. Subsequent actions performed within each paragraph were assigned a sequence number ranging from 3 to x. The data was copied into the Discussion Analysis Tool (Jeong, 2005b) to generate a frequency matrix (Figure 5) that reported the number of times one particular action immediately followed another particular action. For example, the matrix in Figure 5 presents the frequencies for all two-event sequences observed wiki revision histories. The matrix for example shows that when a student added a new paragraph, the most common actions that followed were mEDIT ($n$ = 9), EDIT ($n$ = 9), and ADDo ($n$ = 5).

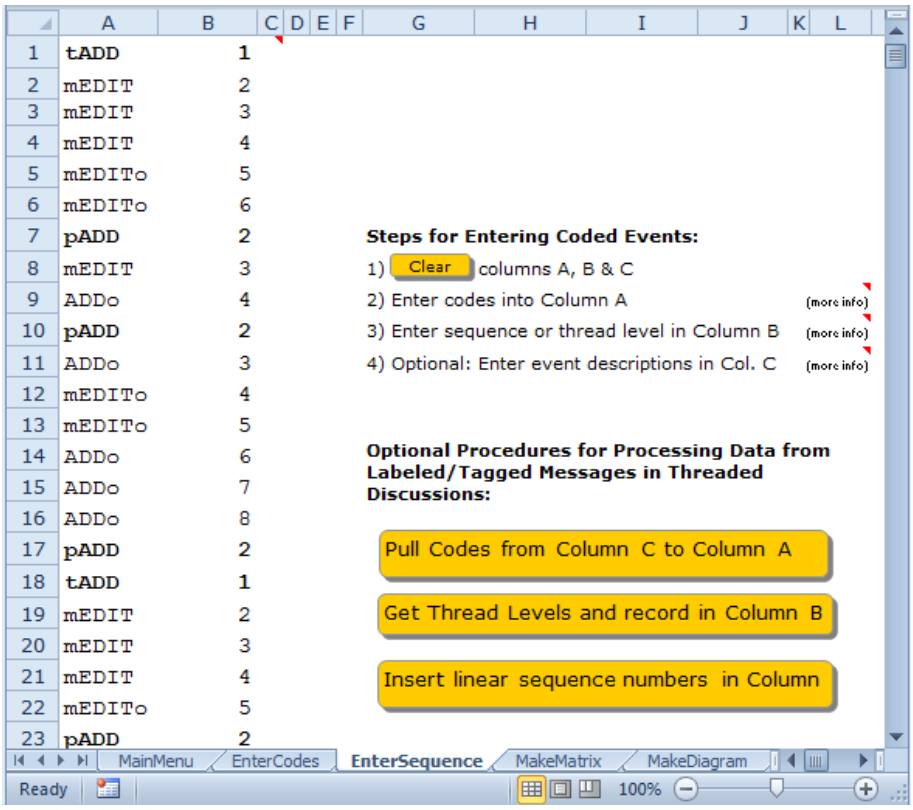



**Figure 4**. Codes and assigned sequence numbers entered into the Discussion Analysis Tool

**Frequency matrix**

| | tADD | pADD | ADD | DEL | EDIT | mEDIT | ADDo | DELo | EDITo | mEDITo | Replies | No Replies | Givens |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tADD | 0 | 37 | 0 | 0 | 1 | 11 | 0 | 0 | 1 | 1 | 51 | 0 | 13 |
| pADD | 0 | 0 | 1 | 0 | 9 | 9 | 5 | 1 | 0 | 1 | 26 | 11 | 37 |
| ADD | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| DEL | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 |
| EDIT | 0 | 0 | 0 | 1 | 6 | 5 | 1 | 2 | 0 | 0 | 15 | 5 | 20 |
| mEDIT | 0 | 0 | 0 | 2 | 0 | 19 | 9 | 0 | 1 | 10 | 41 | 10 | 51 |
| ADDo | 0 | 0 | 0 | 0 | 2 | 5 | 2 | 0 | 1 | 4 | 14 | 4 | 18 |
| DELo | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| EDITo | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 3 |
| mEDITo | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 8 | 11 | 15 | 26 |
| | 0 | 37 | 2 | 3 | 20 | 51 | 18 | 3 | 3 | 26 | 163 | 51 | 176 |

**Figure 5**. Frequency matrix for all two-event sequences based on 176 total actions

Using the procedures for conducting post-hoc single case-study analysis developed by Jeong (2005a), the behavioral patterns performed by students working *individually* on a paragraph/heading were identified by pulling out the cell frequencies from the upper-left quadrant of the frequency matrix (Figure 5) and converting that subset of frequencies into transitional probabilities (see left side of Figure 6). To identify patterns in ways students perform edits on other students' text, the frequencies in the upper-right (Figure 5) quadrant were pulled out and that subset of frequencies was then converted into transitional probabilities (see right side of Figure 6). The *z*-scores presented in the *z*-score matrices determined whether or not each transitional probability was significantly higher or lower than the expected probability (based on chance alone) using a liberal and exploratory critical *z*-score value of 1.64, $p < .10$. Transitional probabilities that were found to be higher than expected (*z*-score > 1.64) are highlighted in green/bold type to help identify the behavioral sequences that can be deemed to be a "behavioral pattern".

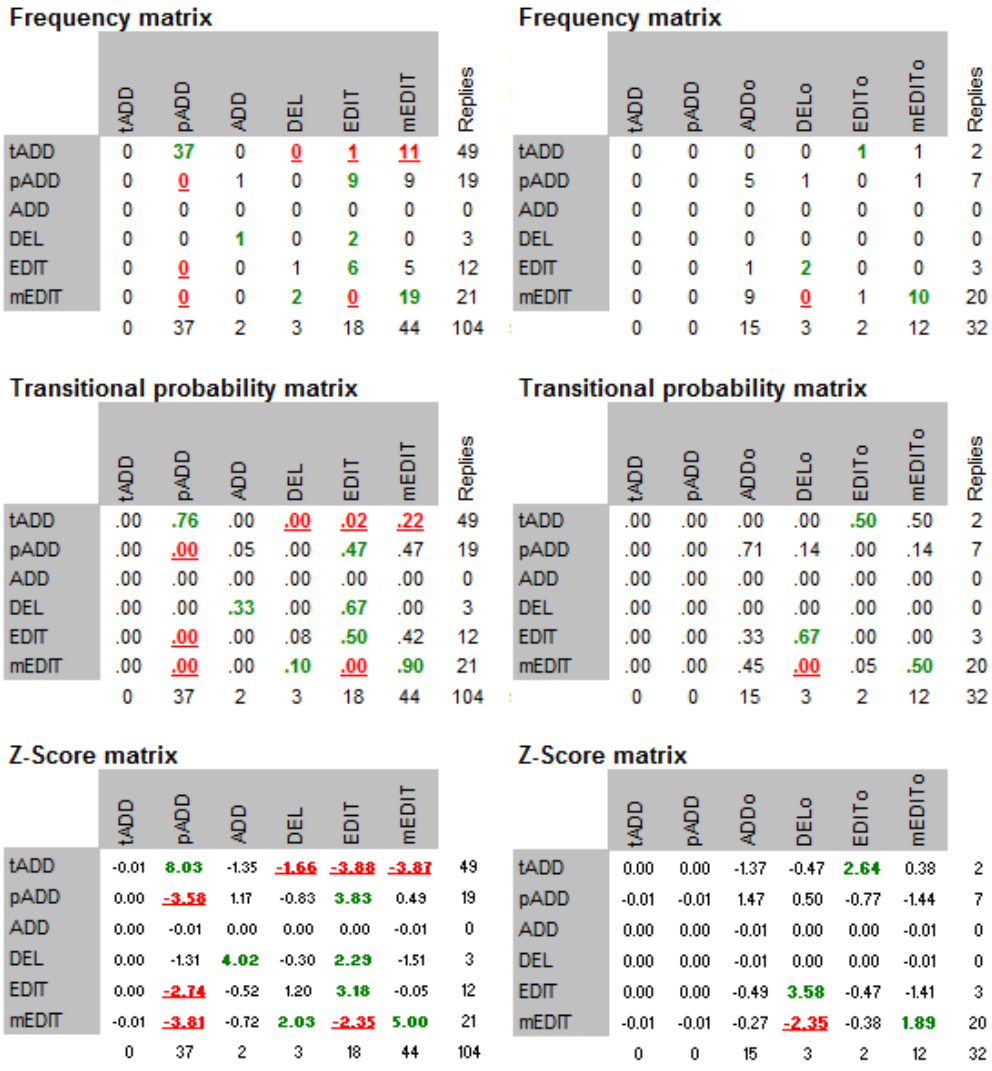



**Figure 6**. Adjacency matrices for individual (left side) vs. peer (right side) editing processes

To obtain a birds-eye view of all the behavioral patterns, the transitional probabilities observed in the individual writing processes were translated into one transitional state diagram, and the probabilities observed in the actions peers perform on another students' text were translated into a second transitional state diagram (see Figure 7). In each state diagram, each node represents a specific action. The frequency in which the specific action was observed is reported in the first numerical value in the node. The action frequencies are also conveyed by the relative size of the circular glow emanating from each node. The second numerical value reported in each node presents the number of actions that immediately followed and/or were trigger by the given action. The links or arrows that point from one node to another node identify which actions were found to immediately follow another action. The weights or width of each link is directly proportional to the observed transitional probability observed between two given actions. Varying the density of the links provides a graphical representation that readily conveys which actions were most vs. least likely to follow another action. Furthermore, the links that are colored black or gray identify probabilities that were significantly higher or lower than expected, respectively. All of these combined features of the state diagrams provide a quick and visual means of identifying similarities and differences in behavioral patterns/processes observed between individual versus peer editing.

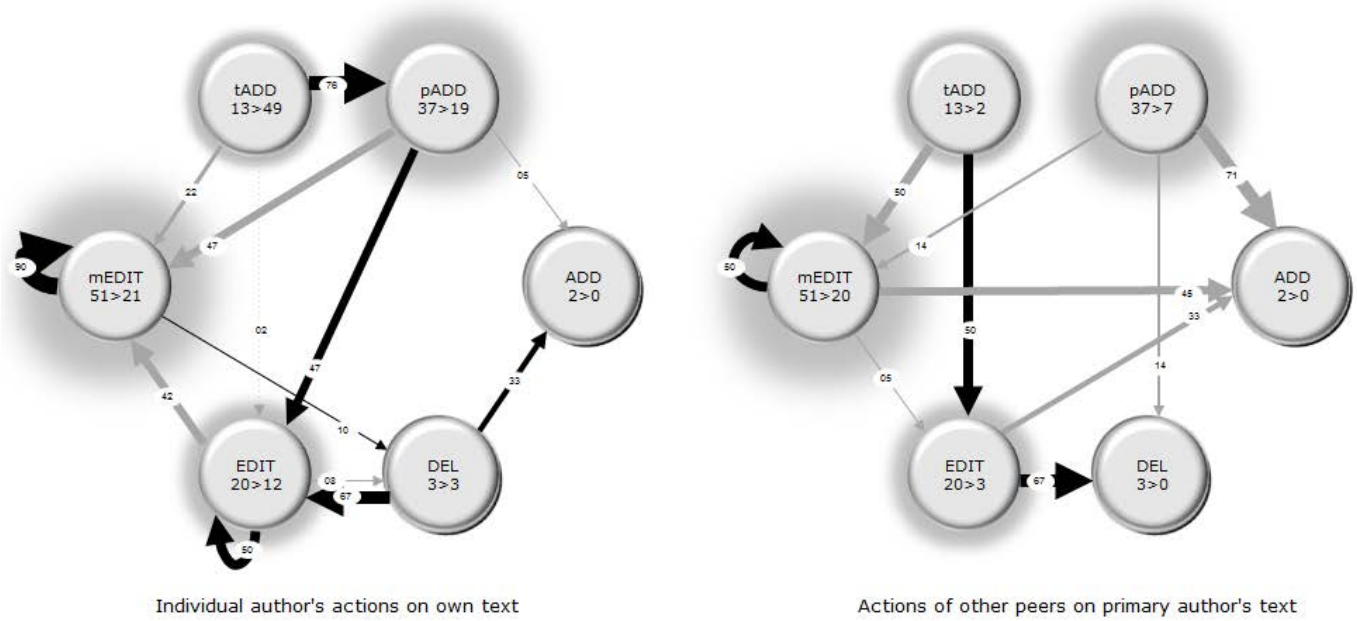
## Main Findings

Even though some cell frequencies in the frequency matrix were too small ($n < 3$) to allow for statistical testing (Bakeman & Gottman, 1997 p. 145), various tests were conducted merely to illustrate how the methods can be used to measure, analyze, identify, and interpret behavioral patterns observed in the wiki.

Sequential patterns in individual vs. collaborative writing processes

The left diagram in figure 6 reveals a total of six patterns in the action sequences students most often performed while working *individually* on their own paragraphs. The diagram shows that once a student added a new topic heading to the wiki, the student was most likely (76%) to add a new paragraph below the topic heading. The addition of the new paragraph was then most likely followed by a major edit (47%), and this in turn was most often followed by another major edit (50%). The diagram also reveals that the actions that were likely to follow a deletion were major edits (67%) and adding new sentences (33%) to the paragraph. Finally, a student was likely to follow a minor edit by performing another minor edit (90%).

The right diagram in figure 6 reveals three patterns in the action sequences that *other* students performed following a given action performed by the author of the paragraph. When one student added a new topic heading (tADD), 50% of the actions on the topic heading performed by other students were major edits. When the original author of a paragraph performed a major edit, other students' actions on the edited paragraph were most likely to be a deletion (67%). When the original author performed a minor edit on the paragraph, the following actions of other students' on the same paragraph were likely to be additional minor edits (50%).




*Notes*: Black and gray arrows identify probabilities that were and were not significantly greater than expected and are weighted in direct proportion to the observed transitional probability. The first and second numerical value displayed in each node identifies the number of times the given action was performed and the number of events that followed the given action. The size of the glow emanating from each node conveys the number of times the given action was performed.

**Figure 7**. State diagrams depicting patterns in individual vs. collaborative writing processes

Differences in individual vs. collaborative writing processes

The differences in the probability distributions of actions a student performs after the student adds a new paragraph (pADD) from the actions *other* students perform after the student adds the paragraph was significant, $X^2(df = 3) = 17.2$, $p = .001$. This finding suggests that the type of actions a student performs on a paragraph once a paragraph has been added to the wiki depends largely on whether that student added the paragraph him/herself or if another student added the paragraph. Specifically, a student that adds the paragraph is much more likely to perform a major edit on the paragraph, whereas students that did not add the paragraph are much more likely to add additional text or sentences to the paragraph.

The differences in the probability distributions of actions a student performs after making a major edit (EDIT) on a paragraph from the actions that *other* students perform after the student makes the major edit was significant, $X^2$ ($df = 3$) =10.8, $p = .013$. This finding suggests that the type of actions a student performs on a paragraph after a major edit is performed on the paragraph depends largely on whether that student made that major edit him/herself or if another student made the major edit. Specifically, a student that makes a major edit is much more likely to make additional major edits to the paragraph, whereas students that did not make the major edit are much more likely to delete text from the paragraph. Why *other* students exhibited the tendency to delete text from the paragraph (rather than make further edits), and the question as to which of the two behaviors (major edits vs. deletions) is more desirable and collaborative in nature has yet to be determined.

The differences in the probability distributions of actions a student performs after making a minor edit (mEDIT) from the actions that peers perform following a minor edit was significant, $X^2$ ($df = 3$) =14.8, $p = .002$. This finding suggests that the type of actions a student performs on a paragraph following a minor edit on a paragraph depends largely on whether that student made

that minor edit him/herself or if another student made the major edit. Specifically, a student that makes a minor edit in a paragraph is very likely to make additional minor edits (90%) to the paragraph, whereas students that did not make the first minor edit are far less likely to make additional minor edits (50%) to the paragraph and much more likely to add additional text (45%).

Altogether, these findings are consistent with previous studies (Ebner, Zechner & Holzinger, 2006; Slagter & Efimova, 2007) that show that students tend to avoid editing other students' work, possibly because students wish to avoid controversy and interpersonal conflicts. Given that each student tended to initiate and work on their own topic headings and the paragraphs within their own topic headings, these findings also indicate that students used more of a parallel rather than a reciprocal approach to coordinating the writing task. The use of a parallel approach is not unexpected given that the students signed up to read and review specific readings from a reading list and because the final group document was not a graded assignment.

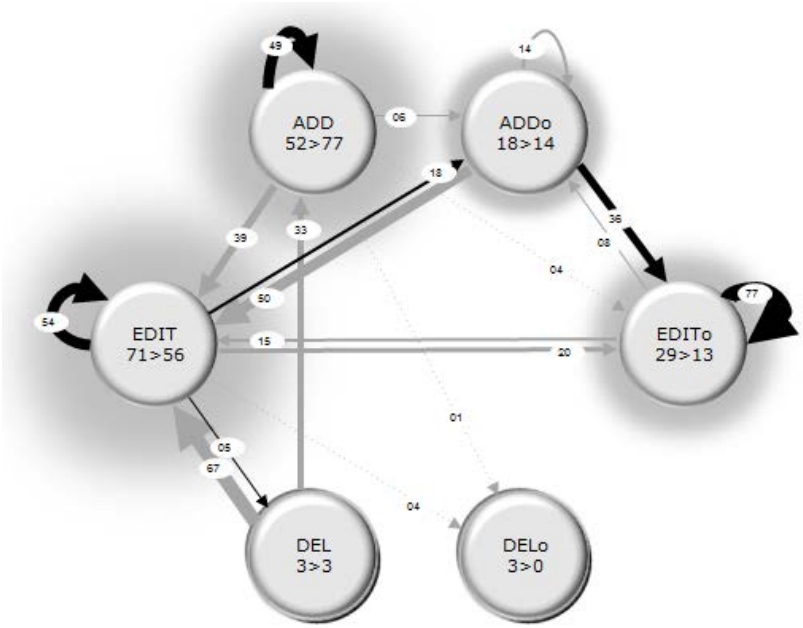



**Figure 8**. The state diagram reveals the transitions between actions performed on any given paragraph by the student that authored the paragraph and by other students (nodes with 'o' tag)

Interplay between individual and collaborative writing

For a holistic and combined view of both individual and collaborative processes used to write and edit any given paragraph within the Wiki, the frequencies for actions that were similar in nature (tADD and pADD; mEDIT and EDIT) were pooled together into a single code (ADD, EDIT) to reduce the total number of codes down to six categories. The sequential analysis of these six codes produced a state diagram (Figure 8) that revealed the following processes used by students in this study: a) when a student added a topic heading or paragraph to the Wiki, the action most likely to follow was the addition of a new paragraph or sentence (49%) posted by the same student; b) once a student added a paragraph and performed some edits on the paragraph, the action that was most likely to follow was additional edits (54%) performed by the same student; c) after edits were performed by the original author of the paragraph, the original author would on occasion (5%) make some deletions on the paragraph, or, some *other* students would add a new sentence to the paragraph (18%); d) when some other students added text to the

paragraph, the action that often followed by edits perform by the other students; and e) and these edits by other students would often be followed by additional edits (77%).

Overall, the state diagram in Figure 8 to an extent reveals the following chain of events that characterizes the collaborative writing process used by students in this study: ADD → EDIT → DELETE or EDIT → ADDo → EDITo. Further study will be necessary to examine and code the semantic nature of the text added by peers in order to determine for example the extent to which peers are adding text to elaborate, build on, or clarify ideas presented in the paragraph, or inserting sentences to qualify and bring to light potential problems, limitations and issues regarding the relevance, accuracy, and veracity of the ideas presented in the paragraph.

In order to determine which prior event is most likely to elicit a desired target action from a student, the "historical" state diagram in Figure 9 reveals the distribution of actions that occurred just *prior* to each action. If studies confirm for example that significantly increases in the quality of a group's document can be achieved by increasing the number of times other students edit the work of another student (EDITo), the historical state diagram suggests that the prior event most to least likely to elicit the EDITo action is a previous EDIT action (38% of the time) vs. EDITo (34%), ADDo (17%), and ADD (10%). As a result, this historical diagram can be used to identify and extrapolate what chains of events are necessary and/or are most likely to trigger any given behavior that is believed to contribute to higher group performance.

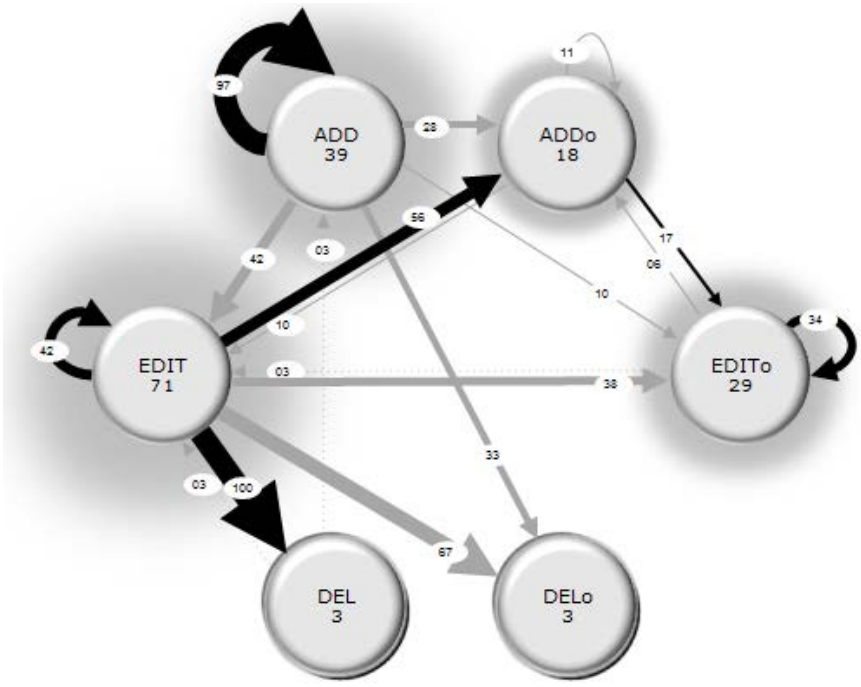



**Figure 9**. This historical state diagram reveals the distribution of actions that occur just *prior* to a given action to help determine the events needed to trigger a desired target behavior

## Conclusions

The methods developed in this study were used to sequentially analyze the individual and collaborative writing actions observed in the Wiki. The findings produced in this study (although not yet conclusive) are consistent with prior research findings and hence serve to illustrate how sequential analysis can be used to support further research on how wikis can best be used to

facilitate collaborative learning. Specifically, this study illustrates how sequential analysis can be used to measure and *operationally define* collaborative writing at a more micro-level in terms of specific action sequences as opposed to macro-level processes and/or coordination strategies – strategies that can be highly variant, difficult to classify, and subject to change over the course of a single collaborative writing assignment (Edes & Lunsford, 1990). With the ability to measure the relative frequencies of action sequences among a wide range of possible action sequences, the methods outlined in this study can be used in future studies to identify and test the processes that promote and inhibit group performance. With a deeper, more precise, and more thorough understanding of the collaborative writing process, new wiki tools, interfaces, and instructional interventions can be developed to foster the action sequences proven to increase group performance and to address the processes that inhibit group performance.

Before we can achieve these goals, however, more research is needed to further develop the methods developed and described in this study. Even though a Wiki can make the writing processes more accessible, coding and analyzing the data is still time consuming and subject to human error. As a result, new software tools are needed to harvest the raw data from Wiki revision histories, implement rules or algorithms to automatically code the data, and automate the data analysis. In addition, further work is need to expand, refine, and further articulate the coding rules in order to fully capture the writing processes with even greater precision in terms of syntactic as well as semantic relationships between students' actions. The various approaches will need to be tested to determine which approach produces measures and process models that best predict and explain group interactions and learning outcomes.

## References


Alexander, B. (2006). Web 2.0 - A new wave of innovation for teaching and learning? *EDUCAUSE Review*, March/April 2006, 33-44.

Augar, N., Raitman, R. & Zhou, W. (2004). Teaching and learning online with Wikis. In R. Atkinson, C. McBeath, D. Jonas-Dwyer & R. Phillips (Eds.), Proceedings from the *21st ASCILITE Conference, Perth, Australia*, 95-104. Retrieved on August 20, 2007, from http://ascilite.org.au/conferences/perth04/procs/augar.html

Bakeman, R., & Gottman, J. (1997). *Observing interaction: An introduction to sequential analysis*. Cambridge, University Press.

Baker, M. (1999). Argumentation and constructive interaction. In P. Courier & J. E. B. Andriessen (Eds.), *Foundations of argumentative text processing* (pp. 179-202). Amsterdam: Amsterdam University Press.

Bakhtin, M. (1981). *Dialogic imagination*. Ed. Michael Holquist. Trans. Caryl Emerson and Michael Holquist. Austin: University of Texas Press.

Dillenbourg, P., Baker, M., Blaye, A., & O'Malley, C. (1996). The evolution of research on collaborative learning. In E. Spada & P. Reiman (Eds.) *Learning in Humans and Machine: Towards an interdisciplinary learning science.* (Pp. 189-211). Oxford: Elsevier.

Driscoll, M.P. (2005). *Psychology of learning for instruction* (3rd ed.) Boston: Pearson Education, Inc.

Ebner, M., Zechner, J. & Holzinger, A. (2006). Why is Wikipedia so successful? Experiences in establishing the principles in Higher Education. Proceedings from *I-KNOW 06, 6th International Conference on Knowledge Management*, Graz, Austria, 5, 527-535.

Ede L. & Lunsford A. (1990). *Singular text/plural authors: Perspectives on collaborative authoring*. Southern Illinois University Press, Carbondale.

Forte, A. & Bruckman, A. (2007). *Constructing text: Wiki as a toolkit for (collaborative?) learning.* Proceedings from *WikiSym'07*, Montreal, Quebec, Canada.

Jeong, A. C. (2003). The sequential analysis of group interaction and critical thinking in online threaded discussions. *The American Journal of Distance Education, 17*(1), 35-43.

Jeong, A. (2005a). A guide to analyzing message-response sequences and group interaction patterns in computer-mediated communication. *Distance Education, 26*(3): 367-383.

Jeong A. (2005b). *Discussion Analysis Tool*. Last retrieved on April 3, 2012 at http://myweb.fsu.edu/ajeong/dat.

Johnson, D. & Johnson, R. (1992). *Creative controversy: Intellectual challenge in the classroom*. Edina, Minn.: Interaction Book company.

Koschmann, T. (1996). Paradigm shifts and instructional technology. In T. Koschmann (Ed.) *CSCL: Theory and Practice of an Emerging Paradigm*, Lawrence Erlbaum, Mahwah, NJ, pp. 1-23

Lamb, B. (2004). Wide open spaces Wikis ready or not. *EDUCAUSE Review*, September/October 2004, 36-48.

Olson, J. S., Olson, G. M., Storresten, M., & Carter, M. (1992). How a group-editor changes the character of a design meeting as well as its outcome. Proceedings from *Computer Supported Cooperative Work Conference* (CSCW 92).

Olson, G., Herbsleb, J., & Rueter, H. (1994). Characterizing the sequential structure of interactive behaviors through statistical and grammatical techniques. *Human–Computer Interaction, 9*(3/4), 427–472.

Palinscar, A. & Brown, A. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. *Cognition and Instruction, 1*(2), 117-175.

Raitman, R., Augar, N. & Zhou, W. (2005) Employing Wikis for online collaboration in the e-learning environment: Case study. Proceedings from the *Third International Conference on Information Technology and Applications* (ICITA'05).

Scardamalia, M., & Bereiter, C. (1996). Engaging students in a knowledge society. *Educational Leadership, 54*(3), 6-10.

Sharples, M. (1992). Adding a little structure to collaborative writing. In D. Diaper and C. Sanger (Eds.) In *CSCW in practice: An introduction and Case Studies*, London Springer-Verlag.

Sharples, M. (1999). *How we write : writing as creative design.* London; New York: Routledge.

Wikimatrix (2009). Last retrieved May 28, 2009 http://wikimatrix.org.

Wiley, J., & Voss, J. (1999). Constructing arguments from multiple sources: Tasks that promote understanding and not just memory for text. *Journal of Educational Psychology, 91,* 301-311.