Wiki and Threaded Discussion for Online Collaborative Activities: Students' Perceptions and Use

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***Abstract*—Investigating the affordances of different web technologies to support online collaborative learning (CL) has implications for future research and practice in online education. In addition to a threaded discussion (TD)—the predominant tool used to promote online collaboration today—we used a wiki with 15 graduate students in an online course. Students worked on two different group activities, first using the TD and then using the wiki. We investigated students' attitudes about their CL experience, as well as differences in their CL processes, after using each technology. Our findings suggest that there are clear benefits and limitations inherent to both technologies. The TD tool was preferred, yet students recognized the potential of the wiki to support collaboration. Practical implications and future directions are discussed, including the need for instructors to support and encourage discussion as a complement to wiki writing, scaffold and model the use of wikis, and create sufficiently complex group tasks to help make wiki use attractive and appropriate.**

***Index Terms*—online learning, wiki, threaded discussion, collaboration, collaborative learning, computer-supported collaborative learning**

I. INTRODUCTION

Promoting collaborative learning (CL) in web-based environments is often highlighted as a pedagogical challenge for instructors [1] [39] [42] [48]. Currently, asynchronous threaded discussion (TD) tools are the predominant means for promoting social exchange, interaction, discussion, and collaboration in online classes [15] [29] [37]. However, there are several studies that have reported disappointing results related to engaging students in online CL within TD environments, e.g., [14] [30] [40] [50] [53]. Meanwhile, wikis are gaining ground as useful CL tools in secondary and higher education, and several researchers and practitioners have endorsed their use for online student collaboration [3] [9] [12] [41] [51]. Nonetheless, more empirical and applied work is needed to support or refute their effectiveness. This study aimed to increase our knowledge of wikis for CL in higher education, with particular emphasis on students' perceptions and use of wikis compared to TD tools.

In addition to a TD forum, we used a wiki tool to support student collaboration in an online learning theories course. Students worked on two different group activities, first using TD and then using wiki. The purpose of this study was twofold: (a) to assess students' attitudes about their CL experience after using the wiki and TD, and (b) to investigate differences in CL processes evident in the wiki as compared to the TD environment.

A. What is a wiki?

Wikis are collaborative editing tools that allow visitors to become editors of a given topic at any time and from virtually any location. The basic premise of a wiki is that anybody can contribute, revise, and delete, and that all changes are instantly visible in a browser window [35].

The first wiki (WikiWikiWeb) was created by Cunningham in 1995. Since then, a number of wiki applications (e.g., DocuWiki, PBwiki, WikiSpaces, MediaWiki) have been developed to support a variety of group projects. Wikipedia, the online encyclopedia, is the largest and perhaps best-known wiki. In short, wikis—and other similar collaborative editing tools such as GoogleDocs—aim to provide an accessible way to publish, collaborate, and exchange ideas over the web [13]. Some features of these tools, such as automatic notifications and history documentation, appear to promote collaboration because community members can immediately monitor and respond to each others' contributions [38].

B. Research on Wikis in Education

In recent years, wikis have become popular as CL tools in secondary and higher education. A notable example of such use is the CoWeb wiki at the Georgia Institute of Technology. Since 1998, CoWeb has been used in a variety of ways, including collection and distribution of information, collaborative artifact creation (i.e., collaborative papers), and critique/discussion of papers. Taken together, research findings have indicated

learning benefits and positive attitudes associated with the use of CoWeb for CL [21] [41].

In general, previous studies of wikis in education have primarily focused on one or more of the following areas:

(a) Wiki features and the types of learning activities they can support [3] [9] [21]. For example, ref. [9] described the implementation of an encyclopedic collection of information on new media concepts and topics, using MediaWiki.

(b) Students' (and instructors') perceptions of wikis as learning tools. These "attitude studies" have generally revealed that students and instructors see value in wikis as CL tools, even though their CL experiences are not always positive [10] [16].

(c) The role of the task and teacher in a wiki; that is, how learning tasks should be shaped, planned, and enforced [36].

Despite the considerable adoption of wikis in education, evidence of their pedagogical benefit as CL tools is inconclusive. Additionally, students' perceptions and use of wiki technology in relation to other, more widely adopted web technologies have not been assessed.

C. Conceptual Framework

We situate this study in the context of the current literature on CL and, more specifically, computer-supported collaborative learning (CSCL).

Ref. [46] defined CL as "a process by which individuals negotiate and share meanings relevant to the problem-solving task at hand" (p. 70). Collaborative learning as a method is consistent with sociocultural views of learning. Such views argue that learning is inherently active, reflective, and social [7] [43] [54] [55]. Sociocultural views also emphasize the critical role of tools as mediators in the learning process [18] [19] [54] [55]. In CL environments, multiple ideas and viewpoints are allowed to be expressed, and students collaborate to produce and share representations of their understandings of the world. What is more, students in CL environments work together in pairs or small groups to accomplish a shared goal, such as solving a problem or creating a product [43] [44] [45] [46]. Some examples of CL activities include debates, group projects or assignments, simulation and role-playing exercises, group work on case-study scenarios, collaborative composition of essays, and small-groups discussions.

The CSCL community focuses on how technology may support peer interaction, collaboration, and knowledge sharing. Drawing again upon sociocultural perspectives, CSCL researchers study how interactions among learners, teachers, and mediating tools can be powerful forces in the learning process, as they support active thinking and knowledge construction [18] [19] [54] [55]. For CSCL researchers, different mediating tools may afford different opportunities for CL, depending on how well they promote or limit CL interactions [24] [46] [49] [50]. This argument goes back to the well-known media debate between Clark and Kozma, where ref. [31] asserted that certain computer tools afford unique opportunities for learning. As such, investigating the affordances of different web technologies to support online CL has implications for future research and practice in online education. With respect to this study, identifying the affordances of wikis to support online CL, and how those affordances differ from widely adopted TD technology, warrants investigation.

Finally, CSCL researchers see CL as a multifaceted phenomenon and, as such, utilize mixed-method research designs to obtain an understanding of collaborative interactions, knowledge construction, and the use of technology without oversimplifying the reality of such use [24] [32] [50]. Consistent with research in CSCL, this study makes use of quantitative and qualitative methods to investigate students' attitudes and CL processes evident in a wiki as compared to a TD environment.

II. METHOD

A. Participants

Participants were 15 graduate students enrolled in a three-credit, 16-week online course in learning theories offered at a large public university in the northeastern United States. Participants were graduate students in an educational technology program, pursuing a Master of Arts degree or a Sixth Year Certificate. The sample consisted of 8 females (53%) and 7 males, ages 24-54. All 15 students were in-service, K-12 teachers; 80% had 1-5 years of teaching experience, and 20% had more than 6 years of teaching experience.

B. Technologies

The TD forum within the WebCT-Blackboard Learning System (Bb) was the primary tool used to facilitate online communication and collaboration in the course. Nearly every week, students were expected to participate in class-wide discussions using the TD in Bb. In this TD, by default, messages are organized in threads; although users *can* choose to view those messages unthreaded and in chronological order.

The wiki environment was built using freely available software called PBwiki. This wiki allowed for collaborative page editing, formatting, and linking; a complete history and audit trail for each page; comments (users could leave comments on a wiki page); and automatic notifications by really simple syndication (RSS) and email, which are meant to help users keep abreast of changes on the wiki environment. PBwiki does not provide a space for discussion.

C. Instrumentation

Based on our literature review, we selected to measure four key variables associated with CL in computer-mediated environments: (a) *perceived learning,* (b) *communication and reflection, and* (c) *satisfaction with the learning experience,* see reviews [30] [53]. Three of these subscales were adapted from previously validated instruments. We also included an additional subscale, *frustration with technology,* to enhance our understanding of online CL using wiki and TD technologies.

Altogether, our CL Survey was composed of 55 items divided into two sections. Section 1 of the survey included 44 Likert-type items with a 7-point agreement response scale: 22 items referred to the first group activity using the TD, and another 22 items referred to the second group activity using the wiki. Section 1 included (a) a 4-item perceived learning subscale that assessed the extent to which students felt the group activity helped them gain new knowledge and skills; (b) an 8-item communication and reflection subscale (adapted from [56]) that assessed the extent to which students interacted with their group members during the activity; (c) a 6-item satisfaction subscale (adapted from [2]) that assessed the extent to which students were satisfied with the group activity; and (d) a 4-item frustration subscale (also adapted from [2]) that assessed the extent to which students were frustrated with the technology used (see Table I for subscale items).

Section 2 of the survey included demographic items, as well as three open-ended questions concerning each technology. Specifically, the open-ended questions asked students about the pros and cons of the wiki and TD technologies, as well as their overall learning experience using the two technologies for the group activities.

TABLE I.
ITEMS CONTAINED IN EACH SURVEY SUBSCALE OF THE CL SURVEY

Perceived Learning (PL)	
PL-1	The collaborative wiki/TD activity has helped me understand the topic.
PL-2	I learned new things about educational theory by working on the wiki/TD activity.
PL-3	The wiki/TD activity was successful in promoting collaborative writing.
PL-4	The wiki/TD activity was successful in promoting knowledge construction.
Communication and Reflection (C&R)	
C&R -1	It was easy for me to communicate my thoughts or opinions to the group using the wiki/TD.
C&R-2	As a technology, the wiki/TD helped me work effectively in groups.
C&R-3	It was easy to respond to other students' ideas using the wiki/TD.
C&R-4	It was easy to explain my ideas to other students using the wiki/TD.
C&R-5	The nature of the wiki/TD technology encouraged my participation in the activity.
C&R-6	During the wiki/TD activity, I reflected on other students' ideas.
C&R-7	The wiki/TD activity helped me think critically about other students' ideas on the topic.
C&R-8	I felt free to criticize the ideas, statements, and/or opinions of others team members on the wiki/TD.
Satisfaction (S)	
S-1	Overall, my collaborative learning experience using the wiki/TD was positive.
S-2	I was satisfied with my online learning experience using wiki/TD.
S-3	I would use this type of online activity if I were teaching an online course.
S-4	I felt the activity met my needs as a learner.
S-5	I would recommend this type of online activity to a friend who was teaching an online course.
S-6	Overall, I enjoyed working collaboratively with other students on the wiki/TD activity.
Frustration (F)	
F-1	I felt frustrated.
F-2	I was angry.
F-3	I felt as though I was wasting my time.
F-4	I was irritated.

D. Procedures

Activity 1. This activity took place during weeks 9-10 of the class and was completed on the TD forum within Bb. The topic of the activity was *Teaching to the Test*. Students were asked to work collaboratively, in groups of 3-4 students, to produce a group consensus response, organized around five questions related to the topic (e.g., "What kind of learning and instruction is being emphasized by No Child Left Behind?" and "One of the criticisms of teaching to the test is that the "test" does not accurately assess what the student knows or can do. Do you agree or disagree with this criticism? What is the literature base for your position?"). Students started by posting their initial thoughts about the topic on a class-wide TD (part a). Then, a private thread was created for each group to discuss the five particular questions (part b). Finally, groups wrote their consensus response on a separate class-wide TD for all other groups to read and comment on (part c).

Activity 2. This activity took place during weeks 11-12 of the class and was mainly completed on the wiki. The topic was *Learning and Technology*. Students started with their initial thoughts on a class-wide TD within Bb (part a). Meanwhile, a separate wiki page was created for each group of 3-4 students in the wiki environment. To "warm-up" with editing wiki pages, students were first asked to create their short bios on their groups' page. All students posted pictures and short bios on the wiki page and none of the students reported having difficulties with the technology. Then (part b), students were asked to work collaboratively on their groups' wiki page to produce a consensus response, organized around three questions related to the topic (e.g., "The Kozma-Clark media debate is over two decades old now. Certainly, technology can do things now that were unimaginable 10 years ago. Do these advances strengthen or weaken either position in this argument? If so, how?"). The activity was completed with groups reading and commenting on each others' consensus responses on the wiki page (part c).

There were four groups of 3-4 students in both activities, but the groups were different for each activity. Groups were formed by the instructor of the course. The instructor sought to group students based on the similarity of their viewpoints—as indicated from their initial thoughts on the topic of each activity (part a)—in order to increase the chances that groups would reach consensus and produce a final response that reflected all teammates' views on the topic.

III. RESULTS

All students (N = 15) completed the CL Survey. Table II summarizes the results from the internal consistency reliability analysis on each subscale. As indicated, all Cronbach's alphas were quite good (>.80).

TABLE II.
*SUBSCALE RELIABILITIES (*N = *15)*

Subscale	No. of Items	Cronbach's Alpha	
		Wiki	*TD*
Perceived Learning	4	.95	.86
Communication and Reflection	8	.84	.87
Satisfaction	6	.91	.96
Frustration	4	.90	.86

Note. The response scale ranged from 1 (*completely disagree*) to 7 (*completely agree*).

For each student in the study, a subscale score was calculated by summing the responses of the items associated with a particular scale and dividing by the number of items in that scale (i.e., variables were un-weighted composite scores). Table III presents the subscale mean scores and standard deviations for the four variables.

TABLE III.
SUBSCALE STATISTICS AND T *TEST RESULTS (*N = *15)*

Subscale	*M* (*SD*)		*t*-test Statistics (Effect Size)
	wiki	TD	
Perceived Learning	4.98 (1.42)	5.78 (.89)	$t_{(14)} = 2.57, p < .05$ (Cohen's $d = 0.67$)
Communication and Reflection	4.95 (0.76)	5.95 (0.94)	$t_{(14)} = 2.38, p < .05$ (Cohen's $d = 1.2$)
Satisfaction	4.78 (1.00)	5.63 (1.55)	$t_{(14)} = -2.91, p < .01$ (Cohen's $d = 0.65$)
Frustration	2.98 (1.39)	2.00 (1.69)	$t_{(14)} = 4.10, p < .001$ (Cohen's $d = 0.63$)

Note. The response scale ranged from 1 (*completely disagree*) to 7 (*completely agree*).

For both technologies, the mean scores were fairly high ($\geq$ 4.78) for the positively worded variables (perceived learning, communication and reflection, and satisfaction) and fairly low ($\leq$ 2.98) for the negatively worded variable (frustration). However, paired samples *t* tests revealed that students favored the TD over the wiki. Specifically, they scored statistically significantly higher on perceived learning, communication and reflection, and satisfaction, and significantly lower on the frustration variable, all in favor of the TD. The effect sizes for these findings were moderate to large for perceived learning, satisfaction, and frustration, and very large for communication and reflection (see guidelines in ref. [11]), indicating that these differences are meaningful and may have practical importance for researchers and users of these two CL technologies [34].

In addition to our quantitative findings, we conducted a content analysis of students' open-ended responses to identify core consistencies and meanings. Overall, students' open-ended responses were consistent with the quantitative findings; in particular, the TD seemed to be the preferred technology, yet students recognized the potential of the wiki to support collaboration.

Advantages of the wiki technology. Regarding the advantages of using the wiki for Activity 2, two main themes emerged from student responses.

(a) *Easiness*. Nearly all students reported that the wiki was easy to use. Some direct student quotes included: (a) "It was extremely user-friendly and easy to navigate. It was very well organized.", (b) "I found it much easier to collaborate with my group than by other electronic means.", (c) "It was an easy mode of communication.", and (d) "It was easy to collaborate."

(b) *Real-time editing facilitated collaboration*. Quite a few students reported that the wiki, particularly its real-time editing capability, facilitated collaboration. Some direct student quotes included: (a) "The ability to edit others' work and seeing the edits done by others facilitated collaboration", (b) "Being able to edit the work of others made collaborative writing easy", (c) "You were able to combine ideas and make the statements more powerful by giving collaborative examples", (d) "You can add to what others are writing to enhance their point", (e) "This may be one of the only ways of collaborating in writing with an online course", (f) "I can see that it could be a great tool for developing a common knowledge on content area topics.", and (g) "The collaborative aspect, creating something greater than each individual could on his/her own was quite impressive."

Disadvantages of the wiki technology. Regarding the disadvantages of using the wiki for Activity 2, one main theme—*editing felt uncomfortable*—was present across students' responses. Some direct student quotes included: (a) "I had a difficult time editing others' work because you do not want to offend anyone", (b) "I felt we did not use it fully since most of us felt weird editing someone else's work", (c) "It was difficult to edit the work of others when you felt they created a complete and detailed answer. In most cases, work was added upon not deleted; therefore unnecessary information was left intact", (d) "I honestly hated to critique others' inputs. I didn't mind adding, but deleting stuff made me feel awkward", and (e) "I found that the initial posts seemed very well written and provided a sort of personal spin on the question that we (the editors) did not seem able to edit to add improvements." This finding was not surprising given that prior research on wikis has reported similar concerns [17] [25] [36] [52].

In the last open-ended question of the survey, students were asked to discuss something about the structure of the activity, or the wiki technology, that hindered their collaboration, and how the activity could be have been improved. A considerable number of students argued that the activity, and particularly the questions asked, were not fruitful for collaboration. For instance, one student explained:

> If the main questions were more of a collaborative nature, then we might have been more inclined to interject in others' statements. When asking more for factual information, it is hard to dispute what someone is writing, if their facts are correct. When asking for opinions, it is also hard to discredit that. I

> think the way the task questions are written can make a difference.

Another student also seemed to implicate the nature of the activity as the reason for the lack of collaboration, but in relation to the learners as beginners in the area of learning theory. Specifically, she stated:

> The nature of the questions seemed to allow for broad personal interpretations. This type of answer is difficult to refute or criticize from the point of beginners at the study of learning theory. I, for one, did not feel as though I had much to offer to the wiki responses of others.

The need for a change in the nature of the collaborative activity was expressed over and over across student responses. Another student was very explicit about what could have been done differently for the activity to have been more successful. She explained that in order to encourage collaboration you need to,

> Provide increasing levels of complexity for questions requiring responses. First, have questions that could spark controversy, but require quite literal references to the texts. Then, include a second level of questions that are application-based and use the wiki to discuss how best to implement an application of a particular learning theory….Last, all practicing teachers could benefit by expanding their teaching tool box. Make the wiki activity result in a product that we can take home to the classroom and implement the next day or the next week.

Her last thought was reinforced by several other students who suggested that the wiki activity should last longer and aim towards creating a class resource.

The same open-ended questions were asked relative to the TD and Activity 1. Not surprisingly, student responses did not only reflect their use of TD for Activity 1 but also their use of TD throughout the semester. In other words, most of the students did not make specific comments about Activity 1 and their use of the TD; instead, they pointed out the pros and cons of the TD technology in general. All themes present in the student responses were consistent with previous research findings.

Advantages of the TD technology. Among the most frequently reported advantages of the TD were its *ease of use* and its *support for discussion and collaboration*, also previously reported in [8] [22] [33]. Some direct quotes included: (a) "It was easy to post questions to other members of the group", (b) "It is very easy to use to post initial thoughts and reactions to others' thoughts", (c) "You can read and respond to others in an active discussion. You post a comment, others respond, you respond back and so on. It is also easy to follow the new posts", (d) "It became an easy form of communication. We had a chance to share our thoughts and ideas without feeling pressured to answer one way or another", and (e) "The advantages were being able to have a dialogue with another student, seeing the ideas and examples provided by others, and adding supplemental material to posts such as attachments and links."

Disadvantages of the TD technology. Among the most frequently reported disadvantages of the TD forum were its (a) *incoherence*, also previously reported in [23] [40], (b) *gaps in response times*, also previously reported in [5] [6], and (c) *too much clicking*, also previously reported in [26]. For example, one student stated:

> Clicking, clicking, clicking…Deciding whether to read the entire thread over again or just a response. It's a bit awkward at moments…You can sort of lose the thread of the conversation if you don't react quickly enough. The purpose is to keep the dialogue going and often there are few or delayed responses to certain postings whereas others garner many.

Two other direct quotes were (a) "I feel that often, there is a lapse between original postings and responses…also, there is often posting of thoughts unrelated to the original posting so that the thread is broken up for a while, and that can be frustrating", and (b) "The discussions can go off topic very quickly, and it can be hard to steer them back without a 24/7 active moderator for the discussion board."

Finally, to better understand the CL processes evident in the wiki and TD environments (i.e., how students came to a consensus and how they drafted their consensus response), we examined the information recorded in the form of the wiki history documentation (who, when, what edit was made on the wiki page) and the archived threads in Bb (who, when, what was posted, and who replied to whom).

Activity 1 (TD – Teaching to the Test). On Bb, students moved from (a) completing their initial thoughts to (b) discussing the topic within their groups as they tried to reach consensus, and finally to (c) going public with their consensus response for other groups to read and comment on. There were four groups of 3-4 students each. Each group had its own thread for their group discussion (part b). The instructor participated in the initial thoughts thread (part a) and consensus responses thread (part c), but not during the groups' efforts to reach consensus (part b).

There were, on average, 20 postings on each group's thread. Typically, in each thread, there were 2-3 postings—rich in new ideas—that guided the discussion. Other postings included (a) *agreements/acknowledgements* (e.g., "Lyn, I think you are right on. Not all children are the same, no test should be the same."), (b) *elaborations on previous ideas*, (c) *monitoring statements* (e.g., "Based on the instructions, we need to answer the five questions specifically, and then come up with a consensus on how our group feels and has responded to the questions" and "I am going to search NASET now to see what I can find there."), and (d) *prompting questions*, which often triggered more *elaborations* on previous ideas (e.g., "Don't you think there should be a different way to assess science knowledge. I wonder how other countries that we compare ourselves to test science knowledge.").

For two of the groups, there was a final posting that summarized the main ideas of the discussion, and all group members agreed with the summary as their consensus before going public. The other two groups trusted one group member to post a summary (i.e., their

consensus response) directly on the public forum, without first approving the summary.

We found no disagreements (or questioning of others' thoughts) throughout the discussions of the four groups. In general, it seemed that students sought to reach concluding ideas and agreements early on in their discussions.

Activity 2 (wiki – Learning and Technology). Students moved from (a) completing their initial thoughts on Bb, to (b) constructing their consensus response on their wiki group page (no discussion among group members took place in the meantime), and finally to (c) commenting on other groups' consensus responses on their wiki pages. Again, there were four groups of 3-4 students each (groups were rearranged from Activity 1). Each group had a separate wiki page. As with Activity 1, the instructor participated in the initial thoughts thread (part a), and again after students submitted their consensus response on their wiki page (part c), but not during the groups' efforts to reach consensus (part b).

There were on average 20 revisions on each wiki page, from the time students started crafting their consensus response (but not including the warm-up activity). Typically, there were only three significant contributions within each group's wiki page. Each contribution was a response to one of the questions on the topic and was posted by a different group member, as suggested by the norms and instructions for the activity. In most cases, the author of a significant contribution encouraged his/her teammates to edit his/her initial argument (e.g., "Team, feel free to edit my argument below."). However, besides the three main contributions, almost half of the other revisions were formatting changes, trivial wording changes, and spelling corrections. A few other revisions included adding short sentences (in the middle or end) to reinforce the initial argument (e.g., "In addition, graphic organizer software like kid-inspiration/inspiration helps the kids brainstorm to organize their thoughts" and "Other examples would include flight simulations for training pilots, perfecting surgeries"), and acknowledgments (e.g., "I really like the way you connected Kozma's possibility of the future to the reality of today with the iPhone."). Acknowledgments were generally deleted before groups went public with their summary.

Despite these small changes, none of the revisions seemed to modify the overall meaning of the initial arguments. That is, whatever was added to the initial argument did not contribute to new understandings of the topic. In a sense, individuals responded to separate questions, posted their arguments one after the other, and did not make efforts to built one strong, thoughtful response altogether as a group. This observation was also noted by at least four students who stated that this was either a disadvantage of the wiki technology or was a way to improve the nature of the wiki activity itself. The direct quotes from student responses included (a) "One disadvantage was that I did not get a sense that the group was constructing knowledge. The entries did not seem to add to one another in a manner that would enhance my understanding of the material.", (b) "The structure of the questions did not give way, for me, for collaboration as much as I would have liked. It seemed that everyone took their question and ran with it.", (c) I'd like to see a wiki started and a concept made richer through subsequent edits. I'm not sure I got that from this activity."

A fourth student went beyond reporting the problem to actually comparing the wiki and the TD with respect to supporting students' collaboration. His preference towards the TD technology was apparent as he stated:

> Many of the participants did not feel comfortable or saw no need to edit what their group or other groups posted. In a sense, those that did...it almost felt forced. Adding information to the topic was a positive and helpful point, but editing and deleting was not. The wiki also took away the collaboration that a discussion board has. The groups posted and for the most part, that was it. In the discussion board, the class is actively engaged with the topic. It also could be that the choice of viewpoints and articles made the whole case less attractive than the other.

IV. DISCUSSION

Students did not collaborate on the wiki environment in the manner we had hoped. Phenomena such as *negotiation* and *sharing of meanings* [46] were not present in our wiki environment. Several factors contributed to what appears to have been a "less successful" collaboration (when compared to the TD).

First, students noted that they were reluctant to edit each other's contributions on the wiki, which is consistent with prior research on wikis [13] [25] [36]. In fact, following the recommendations offered in previous investigations, we (as the instructors) attempted to foster collaboration by encouraging students to edit texts created by their group members [36] [52]. Yet, this method seems to have added some extra pressure on the collaborators. In their open-ended responses, two students said: "I felt forced to edit the work of others, for the purpose of the activity" and "I did not like feeling forced to edit the work of others." In a recent study that used wikis to support teacher professional development [17], the researchers experienced the same difficulty, with teachers reluctant to edit the work of others. These researchers suggested that scaffolding of the process (i.e., providing students with assistance regarding what to contribute and when to edit a page) should improve this problem. Like Foley and Chang [17] we too believe that instructor modeling and scaffolding would likely improve the editing process for students. The question becomes—what is the most effective way to scaffold this process? Clearly, more research is needed to address this question. In particular, future investigations should focus on how (and how much) instructors should model and scaffold the use of wikis in order for successful CL to occur using wikis.

Difficulty with editing the work of other students may have been reinforced by the idea that most (if not all) of the students were using wiki technology for the first time. In this sense, students did not have the chance

to get in the "spirit" of being "true Wikipedians"; that is, believing that anyone is able to provide information regardless of his/her knowledge and expertise; knowing that each post is subject to editing by other users; and understanding that editing, deleting, and adding information is necessary in order to create a document that is more accurate and more complete than what one person could generate alone [20]. Future studies might do well to introduce the wiki earlier in the course, while trying to get students to behave like true Wikipedians before assessing the affordances of wikis to support online CL.

Additionally, our students reported that the restrictive nature of Activity 2 was problematic. It was apparent from student responses, and our own observations, that the structure of the activity, including its norms and procedures, did not encourage collaboration. Instead, the activity seemed to support individual accountability and then group processing, characteristics of cooperative learning [47]. Some thoughtful ideas about how to change the structure of the activity to promote collaboration were provided by several students in their open-ended responses. Specifically, three students suggested that the activity could aim for the creation of a class-built, online resource, which could become a knowledge base for the entire class. We agree that this kind of activity may be more authentic and fruitful for collaboration. In addition, we believe that such an activity could possibly make the affordances of wikis more apparent, i.e., the ability of wikis to support sharing of meaning and knowledge creation [12] [41].

The lack of a discussion tool within the PBwiki tool seemed to be another factor that hindered collaboration. In their suggestions for improving the wiki activity, several students argued that PBwiki should include some form of discussion board or instant messenger to make communication more accessible. In fact, one person was very specific, suggesting that MediaWiki (the wiki platform used by Wikipedia) might be a better wiki software choice. He stated:

> Another thing was the limitation of the wiki tool that we used. My understanding is that there are other wikis with more tools. For example, Wikipedia has a discussion area where contributors can negotiate various issues. That way there is more discussion and comfort. I think a discussion area could have been valuable for us, possibly improving the activity.

Indeed, there are available wiki tools that include a place for discussion (threaded or non-threaded). Certainly, choosing a wiki tool that makes communication more accessible may help instructors implement more successful collaborative activities. Future studies should examine the combination of using both wiki and TD to support CL, particularly when students are tasked with coming to a consensus on a topic and creating a written consensus statement. The wiki-TD combination might come in one platform (e.g., MediaWiki), or as two separate technologies integrated into the course. How the affordances of each technology are perceived and used by students is an interesting question that is yet to be addressed.

Related to the above suggestion is our observation that students did not make full use of the wiki environment. For instance, PBwiki offers a comments feature (i.e., users can leave comments on a wiki page), but none of the students took advantage of it. Students either did not know this feature existed or did not think it was useful. On the other hand, it seems that at least two students used the automatic notifications by RSS and email. These students discussed the automatic notifications as an advantage of the wiki environment (e.g., "The email notification helped to prompt me to look at the revisions and read other groups' pages."). Wiki applications usually come with a variety of features, besides editing and linking shared pages. However, students may not notice and/or take advantage of these features, unless the instructor (or other expert) introduces, models, and scaffolds their use. Clearly, in our case, where students had limited experience using the wiki, it was not surprising to find that many students did not use these advanced wiki features.

Finally, it would be unfair to blame the lack of successful collaboration on the wiki technology or the nature of the topic itself (or both). Our analysis of students' CL processes for Activity 1 (Teaching to the Test) suggests that, even when students had more opportunity for discussion on the TD forum within Bb, they did not negotiate and share meaning to the extent we expected. Although there was more activity on the TD environment, the discussion tended to be focused on two or three initial arguments; beyond these, very little was contributed, other than elaborations and examples. For instance, all students seemed to agree that high-stakes testing puts pressure on teachers and students. Moreover, students felt that this pressure limits student creativity and motivation, as well as the teacher's ability to take risks with more constructivist teaching methods. Thus, our students reached consensus early in the discussion, while some relevant and important issues remained unexplored (i.e., what would be a fair alternative to high-stakes testing?).

We draw three recommendations for future studies based these observations. First, the collaborative activity should be complex and require high levels of interdependency within groups [27] [28] [49]. That is, the problem of the activity should be open to different interpretations, and there should be no obvious desirable response. We believe that problem-solving activities, such as case studies, could be fruitful for negotiation of meaning and collaboration among online teacher-learners. Second, we believe the instructor should actively support and encourage student discussion, which may ultimately help students as they attempt to reach consensus. Stated another way, if we really want students to negotiate and share meaning, instructors must be present to prompt students to consider all aspects of the problem, and consider possible alternatives, before they reach early conclusions and consensus. Third, the instructor should model and scaffold the use of the wiki for collaborative

writing in an attempt to help students adopt the "Wikipedian spirit." Clearly, however, more research is needed to better understand the best means of implementing these three recommendations.

V. CONCLUSIONS

Findings from this study suggest that there are clear benefits and limitations to using the wiki and TD technologies for online CL. Based on our quantitative measures, students favored the TD over the wiki. However, student responses to the open-ended questions revealed that they also recognized the potential of the wiki technology to support collaboration, especially when a discussion feature is available and the nature of the activity is less restrictive.

This balance of pros and cons of each technology is well articulated in one student's response about the disadvantages of the TD technology. The student compared the two technologies and came to the following conclusion:

> I think the wiki can be a real eye opener. It's very different from the discussion boards, where you constantly find yourself clicking and trying to follow threads. The wiki offers an at-a-glance method to put many opinions on a page. I like not having to click all over the place. That said, there is a certain (imagined) intimacy to the discussion board, and also, if done correctly, a chronological/sequential building up of a discussion which is not so apparent on the wiki (unless you color code it, as we did with our comments). You can truly argue your points with various people. The wiki forms a whole whereas the discussions boards are snippets of dialogue developing over time.

Based on our observations, we generally agree with this observation. We also believe that challenging, problem-solving activities (such as case studies) would likely be more fruitful for collaboration. In addition, we believe that scaffolding the CL process while students attempt to reach consensus, as well as scaffolding effective use of the technology, would likely improve student learning and collaboration. Finally, we suggest that one tool is not simply *better* than another. Instead, we agree with ref. [31] and other CSCL researchers that certain computer tools afford unique opportunities for learning (collaborative and otherwise). Identifying the affordances of wikis to support online CL, and how those affordances differ from TD technology, is a laudable goal that is in need of further investigation.

Finally, the present study was a descriptive account of our experience using the wiki and TD technologies with students learning online in an educational technology program (and enrolled in a learning theories course). As such, our specific findings do not necessarily generalize to other online learners and contexts. Additionally, our findings are not generalizable to settings where students work in dyads or larger 3-4 member groups. There is some evidence to support the notion that 3-member groups collaborate differently than dyads or larger-sized groups [49]. Furthermore, we used two different activities/topics across the two technologies, which introduced another uncontrolled factor in our comparisons. Future investigations should consider comparing the use of different technologies by comparing subgroups of students performing the same activity.

With regard to our methodology, the descriptive nature of our study does not allow for causal conclusions concerning the affordances of the TD and wiki technologies to support online CL. Therefore, it is important that future studies utilize experimental and quasi-experimental designs to investigate the unique affordances of these technologies. Moreover, design-based research methods [4] may be particularly valuable as researchers and practitioners alike attempt to determine the best combination of instructional practices and interventions to effectively support CL using both wiki and TD technologies.

Ultimately, findings from the current study should not be taken as final statements about the value of wiki and TD technologies to support CL. Instead, we hope this study provides direction and motivation for future investigations. In particular, many practical questions still exist, such as (a) how (and how much) should instructors scaffold and model the use of a wiki for collaborative writing?, (b) how complex should group tasks be in order to make wiki use attractive and appropriate?, (c) how do students come to a consensus on a topic using a wiki?, and (d) what are the educational benefits of integrating both wiki and TD technologies in an online course? These are important questions that warrant further investigation in future work.

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