Supporting Active Wiki-based Collaboration

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Abstract: Prior research has established that active participation and collaboration by students results in multiple benefits during wiki-based CSCL activities. However, achieving such behavior can be a challenge without external motivation. To increase active participation and collaboration by users, we developed an enhanced wiki called the Written Agora. Using popular Web 2.0 features, our wiki provides additional means of participation and aims to encourage direct communication and collaboration between users. Additionally, using intelligent features, we enable the wiki system itself to also participate during collaboration. In this paper, we analyze the results of a study using the Written Agora in a classroom for two semesters. We discover that simply including such features is not necessarily enough to cause their use or improve collaboration. However, encouraging the use of these features resulted in not only greater than expected use, but more diverse and higher quality collaboration by users.

Introduction

Within recent years, one popular tool for computer supported, collaborative learning (CSCL) has been wiki software. Wikis have been used for a wide-variety of CSCL activities, including hosting supplementary material to classroom lectures (Cole, 2009), building glossaries of important terms (Peterson, 2009), group essay writing (Khandaker & Soh, 2009), and contributing to a publically shared knowledge-base (Lampe et. al, 2012).

The use of wikis for CSCL has resulted in several positive, documented results. For example, Wheeler et. al (2008) found that students wanted to create high quality content given the possibility and excitement of broad information dissemination, as well as a self-reported increase in student writing and critical thinking skills. Cress and Kimmerle (2008) developed a model of student interactions with a wiki, focusing on assimilation (addition of new knowledge) and accommodation (reconstruction of existing knowledge) both *internally* within students and *externally* in the wiki between a group of collaborating users. Based on this model, Moskaliuk, Kimmerle, and Cress (2008; 2012) verified that features of wiki content (e.g., levels of incongruity, redundancy and polarity with student prior knowledge) can encourage student learning. Lampe et. al (2012) observed that some students were motivated to continue contributing to wiki systems such as Wikipedia (http://www.wikipedia.org) after producing content as part of classroom activities. Thus, using a wiki for CSCL can benefit students both during classroom activities, as well as beyond the classroom.

However, one common concern has been revealed from the use of wikis in CSCL. Specifically, several studies (e.g., Ebner et. al, 2008; Cole, 2009) report that students tend not to participate in wiki activities without proper external motivation (e.g., requiring participation by assigning points towards grades). This lack of participation is troublesome because without contributing during wiki-based activities, students will fail to achieve the aforementioned benefits of using a wiki for CSCL. Furthermore, research outside of CSCL has also documented the benefits of and concerns over active participation during wiki activities. For example, users who are more active while first exploring the wiki system are much more likely to continue participating in the community in the future (e.g., Panciera et. al, 2009; Antin et. al, 2012). Thus, initial buy-in is very important. Furthermore, Kittur and Kraut (2008) and Arazy and Nov (2010) found that articles on Wikipedia that contained more active collaboration by users (e.g., high levels of activity on the corresponding "discussion" page where users can leave comments for other users) achieved a higher subjective quality (e.g., content accuracy and completeness). Therefore, active participation by users is paramount to achieving the benefits of wiki-based activities both for individual users (e.g., student learning) and the system (e.g., better quality content).

In order to improve the use of wikis as a tool for CSCL, we propose an advanced, intelligent wiki system called the **Written Agora.** Within the Written Agora, we augment the traditional wiki framework with additional features designed to offer more modes of collaboration to encourage greater participation by users. To achieve this goal, we leverage popular features common to other collaborative Web 2.0 applications (e.g., Amazon, http://www.amazon.com; Facebook, http://www.facebook.com; Reddit, http://www.reddit.com) with which users are likely already familiar, such as page ratings, keyword tagging, and threaded discussions. These additional features enable users to participate in different ways than they would in a traditional wiki (e.g., just by viewing and editing pages), hopefully endearing or empowering users and subsequently increasing participation. That is, users who might not have been comfortable or well equipped to participate in traditional wiki-based activities now have additional ways to contribute to the collaboration process, such as providing feedback or summarizing the key content of pages. These software features also provide additional means for external assimilation and accommodation (Cress & Kimmerle, 2008) through adding additional information to wiki pages (e.g., ratings) and coordinating transformations of knowledge (e.g., threaded discussions), which could boost student learning similar to features in wiki content (Moskaliuk, Kimmerle & Cress, 2008; 2012).

Furthermore, we also add *intelligent* features to enable the wiki itself to be a *proactive participant* in collaboration while supporting users with their tasks. For instance, as a user browses pages in the Written Agora, we provide automated recommendations of similar pages the user might be interested in viewing based on the content of those pages. This improves the end-user experience by both helping the user navigate through the broad expanse of topics present in a collaborative wiki to target topics of interest in greater depth, as well as improving user knowledge by encouraging increased usage of the wiki. Moreover, it potentially decreases the burden of initial system usage, which could result in more active and sustained participation by users. Similar intelligent features have been demonstrated to be beneficial to wiki participation both (1) within a CSCL setting, such as intelligently forming groups which increases participation (Khandaker & Soh, 2009), and (2) outside of CSCL, such as recommending pages to edit or content to include in order to increase page quality and coverage (Cosley et. al, 2007; Kong et. al, 2010).

In this paper, we evaluate an experimental study conducted to investigate the impact of including additional Web 2.0 and intelligent features within the Written Agora to increase active participation by students. We consider the results of deploying our wiki system over the course of two semesters in an undergraduate classroom setting. Consistent with prior results of general wiki usage (e.g., Ebner et. al, 2008; Cole, 2009), we find that simply including such features is not necessarily enough to result in their use or improve collaboration. However, encouraging the use of these features resulted in greater than expected use and *more diverse* and *higher quality* collaboration by users. Therefore, their inclusion does result in a net benefit for students, but does not necessarily address the active participation concern. Based on our results, we hypothesize several possible avenues to tackle this important problem without requiring external motivation (e.g., graded participation).

The Written Agora

The features of the Written Agora can be categorized into three primary categories: (1) **traditional** features commonly found in other existing wiki systems, (2) additional **Web 2.0** features, used to offer further modes of participation and to enhance communication between students, and (3) **intelligent** features, enabling the system itself to actively participate in collaboration and support user activities. Table 1 summarizes these features. In the following, we elaborate on the additional Web 2.0 and intelligent features studied in this paper.

Table 1: Features of the Written Agora

Category	Purpose	Features
Traditional	Provide support for common wiki-based activities.	• Create, view, edit, and delete pages with rich text • View and compare page revision history • Control viewing and editing access to pages • Add, view, and delete multimedia attachments • Browse and search for pages
Web 2.0	Enable more modes of participation and advanced user collaboration behavior.	• Rate pages • Tag pages using keywords • Converse in threaded discussions
Intelligent	Enable the system to proactively participate during collaboration and support users' activities.	• Track user behavior during activities • Extract important keywords from pages • Recommend pages based on keyword similarity

Web 2.0 Features

Beyond traditional wikis, the Written Agora includes additional Web 2.0 features common to many other types of contemporary collaboration systems on the web (e.g., social networking sites). These features provide additional means of participation for users, and also enable advanced collaboration and enhanced communication between users to promote improved collaborative work and higher quality pages. Additionally, the features enable the wiki system to store not only the *end product* of collaboration (e.g., shared knowledge), but also *by-products* (e.g., ratings, consensus) and serve as a self-contained *process* for collaboration without the need for coupling with external tools (e.g., email, instant messaging), which could be inconvenient for users.

Page Ratings: Users can rate pages based on their quality using a scale from 1 (bad) to 5 (great) stars. Ratings from multiple users are scored using a cumulative average to define an overall user-supplied quality metric on pages. The overall and current user's ratings are displayed on each page, as well as when browsing for pages, to assist users in quickly evaluating whether a page might be worth reading to increase their own knowledge, or whether or not a page is a good candidate for their editing to improve the overall knowledge within the system. Prior work has shown that visualizing information about pages can improve trust in the information stored in wiki systems (Kittur et. al, 2008), which we believe might also be achieved through community ratings.

Keyword Tagging: Users can also tag pages with important keywords, useful for both (1) summarizing the important concepts within a page, as well as (2) organizing pages around similar topics. Moreover, tag clouds

displaying the most popular keywords based on their frequency of use allows users to observe a current snapshot of the current knowledge within the wiki system. Keywords also assist with page navigation towards topics of interest—clicking on a keyword either on a page or in the tag cloud searches for all pages either tagged with that word or containing the word in its content.

Threaded Discussions: Each page supports collaborative discussions between users through threaded comments, allowing users to start new topics of discussion and respond to one another's comments. For example, users might organize their edits for the page, mediate conflicts, or propose new ideas and suggestions to improve the quality of the page. They can also ask questions of one another and receive direct responses to promote enhanced understanding of the page's content. These discussions provide organized, topic-based communication, in contrast with a more free-form and less organized style of discussion, as in discussion pages on Wikipedia.

Intelligent Features

Another novel aspect of the Written Agora is the inclusion of intelligent features, common to other applications with intelligent user interfaces. These features enable the system to provide its own active support to individual and group user activities. For example, the system can assist users when searching for desired information by leveraging its own knowledge of the system's contents, and it can organize its content and link related pages based on shared topics. Our intelligent features are powered by a multiagent system adhering to the Adaptive Knowledge Assistants framework (Eck & Soh, 2012), where individual and system agents are used to provide tailored support to user activities within the Written Agora.

Keyword Extraction: Similar to keyword tagging by users, the Written Agora also automatically analyzes every page and extracts the most important keywords, which assists users in (1) finding relevant topics within pages, as well as (2) organizing pages containing similar concepts and ideas.

Page Recommendations: Moreover, using the keyword content found by automated extraction and tagged by users, the system also recommends similar pages to the one the user is currently viewing. These recommendations are presented in an unobtrusive side panel to help the user navigate through the wide expanse of the system's content without distracting the user from her current activities. Such recommendations are useful for assisting the user improve her knowledge through both the breadth of related concepts to the current page in the wiki, as well as the depth of understanding of the current topic by targeting pages describing the topic in more detail. Of note, this feature differs from prior recommendations in wikis (e.g., Cosley et. al, 2007; Kong et. al, 2010) in that our recommendations are intended to grow each *individual's* internal knowledge through exploring existing pages, rather than intending to grow the *community's* external knowledge through expanding the shared information in the system. In the future, we plan to explore both types of recommendations.

User Tracking: The Written Agora monitors and records all user activity within the wiki, including which page revisions are viewed by users, which keywords are tagged or removed from pages, and what recommended pages are viewed. For each activity, the system tracks: (1) who performed the activity, (2) what activity was performed, (3) when the activity occurred, (4) what page the user was viewing, and (5) any object corresponding to the activity (e.g., rating, comment). Using this tracked information allows us to evaluate the collaborative behavior of users and provides information to know how best to support users during their collaboration.

Study and Methods

As described previously, the primary purpose of the design of the Written Agora was to create an advanced wiki system that (1) encourages opportunities for participation between users, and (2) actively participates with users in the collaboration process. We conducted a user-based study evaluating the impact of support provided by the Written Agora on user activity and collaboration through both additional Web 2.0 and intelligent features. In the following, we outline (1) the research questions guiding our study, (2) our proposed hypotheses answering these questions, (3) the data set used for our analysis, and (4) the methods used to evaluate our hypotheses.

Research Questions

Guiding our research in CSCL through the use of the Written Agora are two primary research questions, each corresponding to different types of support for active participation and collaboration:

Q1: How does the inclusion of Web 2.0 features intended to encourage more opportunities for participation, as well as active communication and collaboration between users, affect the activities and performance of users?

Q2: How does the inclusion of intelligent features intended to enable the system to become an active participant during collaboration through interactions with users affect the activities and performance of users?

With respect to Q1, we aim in this study to assess the impact of including (1) page ratings, (2) keyword tagging, and (3) threaded discussions in the wiki system in order to potentially increase active participation and

collaboration amongst users. With respect to Q2, we aim to assess the impact of including (1) automated keyword parsing, and (2) related page recommendations on the overall collaboration activities of users.

Hypotheses

Based on these two research questions, we propose several hypotheses stating our expectations about the impact of Web 2.0 and intelligent features on user participation and collaboration:

H1: The inclusion of additional Web 2.0 features will increase the amount of user activity and collaboration.

H2: The inclusion of additional Web 2.0 features will provide more opportunities for participation and collaboration, spreading out activity from only a few users (e.g., Panciera et. al, 2009; Antin et. al, 2012) to most users.

H3: The inclusion of intelligent features will result in more page views (through searches for related pages with similar extracted keywords and followed recommendations).

H4: The inclusion of Web 2.0 and intelligent features will boost the quality of collaboration through more active collaboration amongst users and with the system.

While these hypotheses are intuitive responses to the research questions posed above, they are not guaranteed to hold true in practice. For example, we might observe that collaboration fundamentally follows a power law distribution (Antin et. al, 2012) where only a few users perform nearly all activities, regardless of the type of activity (e.g., editing, rating, commenting) while other users perform few if any activities. If so, the additional features might not result in any increase in total participation as the few active users are already near a maximal amount of activity without these features. Furthermore, the inclusion of intelligent features could have no impact on user behavior as users might not trust or simply ignore the system's active participation.

Data Sets

For this study, we consider two semesters of deployment (Fall 2011 and Spring 2012) of the Written Agora branded as the Duckweed Paper Exchange (DPE, http://duckweed.unl.edu), a component of the Duckweed Project (http://www.unl.edu/cbrassil/duckweed-project-0) within the School of Biological Sciences at the University of Nebraska-Lincoln. In this project, students conduct group-based lab experiments studying the growth of *Spirodela polyrhiza* in different treatment conditions. Based on these experiments, students write their own individual reports about their group's activities, and then the entire group collaboratively forms a final group report detailing their experiment. Within the Duckweed Project, the DPE serves as a tool and repository for the creation and archival of these group reports. Moreover, the reports within the DPE constitute a student-produced journal, where students consider past reports in the design of their own experiments and reference prior work by other students in their own reports. Using the DPE, students practice scientific writing.

Prior to our study, the DPE was prepopulated with one previous semester's group reports (written without the DPE) as an initial seeding of content, as well as one semester's initial usage of the DPE as a pilot study to evaluate the feasibility of the DPE. Thus, between two and three semesters worth of prior reports were available during our study for students to view, rate, and discuss in order to guide their experiments and writing. In both semesters, students were only required to create their final group report using the DPE. Alternatively, they were also allowed to create their own individual drafts within the system before forming a group report, although this step could also be performed outside of the DPE. In the Fall 2011 semester, Web 2.0 features were offered for use but students were not required to use these features. Later, in the Spring 2012 semester, students were required to perform a minimum level of collaborative activities to encourage further collaboration amongst students. These requirements included rating 3 pages, tagging 2 keywords, and offering 5 comments. Moreover, for this later semester, we added the intelligent features considered in our study (automated keyword parsing and related page recommendations). Overall, 47 and 41 users from the Fall 2011 and Spring 2012 semesters agreed to participate in our study, respectively. Of these users, 36 and 28, respectively, agreed also to allow us to consider their earned grades in our study. Thus, our data sets consist of all of the activities performed by these 88 users, including the use of the Web 2.0 and intelligent features in the DPE, as well as the grades earned by 64 users. We would like to note that the grading of student reports was performed by impartial graduate teaching assistants assigned to the course who were not part of our research project. They were made aware that a study was ongoing, but were not given information about what the study measured or our analysis approach. Thus, there was no bias in the grading to impact our results.

Evaluation Methods

To evaluate our hypotheses, we propose the following methods. First, we consider the level of participation and collaboration by users *cumulatively* in each semester, measured by counting the number of times users performed each type of action: ratings, keywords added, comments, recommendations followed, edits, and views. These values are compared against one another both (1) *within* each semester to assess how users collaborated as a collective whole and how the use of one type of activity affected the other types of activities performed by

users, and (2) *across* semesters to determine how the requirement of using Web 2.0 features affected user collaboration behaviors. Second, we also look at the relationships between feature usage (measured using correlations) to learn more about how individual users who exploited or ignored the Web 2.0 and intelligent features behaved in general. Our goal is to better understand the relationship between these activities and user behavior, including whether or not users adopted specific collaborative roles through the use of these features. Finally, we also evaluate the *quality* of collaboration by comparing the grades received for the groups' reports. Here, we aim to understand what relationship exists between the level and type of participation and collaboration performed by users and the quality of the end product of collaboration.

Results

Use of Additional Web 2.0 Features and their Effect on Collaboration

First, we analyze the use of the additional Web 2.0 features during the users' wiki-based activities while writing their reports in wiki pages. To evaluate how often these features were exploited during collaboration, we present the number of actions performed per user, ranked in decreasing order, in terms of (a) ratings made, (b) keywords tagged, and (c) comments posted from both the Fall 2011 and Spring 2012 semesters in Figs. 1a-c.

From these figures, we observe that in the Fall 2011 semester when usage was not required, very few students used these features during their wiki-based activities. In fact, of the 47 users participating in our study, only 3, 7, and 9 users rated pages, tagged keywords, or posted comments, respectively. Moreover, the few users who did exploit these features used them very infrequently. Thus, simply including additional types and modes of collaboration did not necessarily increase the level of participation by students. This matches the results from previous studies of wiki-based activities for CSCL where few users participated without external motivations (e.g., graded requirements) (Ebner et. al, 2008; Cole, 2009). However, we observe a dramatic change of behavior in the Spring 2012 semester *when minimum levels of activity were required*. Here, a larger percentage of users not only used these features to meet the minimum requirements (represented by horizontal black lines in Figs. 1a-c), but most users went *above and beyond* what was necessary. This implies that once users were encouraged to use the features, they perceived a greater value in their use through experience and made greater use of these features than necessary. We hypothesize that *the use of Web 2.0 features in wiki-based collaboration requires reaching a (albeit small) "critical mass" where enough users make use of the features for their benefits to be perceived and their use sustained by the community*. In the future, we plan to further investigate how to achieve and sustain such a crowd-based effect without requiring external motivations.

Second, we analyze the effect of the use of Web 2.0 features encouraging more active collaboration amongst users on both the (1) behavior and (2) quality of collaboration. We begin by presenting the number of pages edited per user in decreasing order in Fig. 1e. We observe that the use of Web 2.0 features appear to have had a significant effect on the editing behavior of users. On the one hand, in the Fall 2011 semester when users made little use of the Web 2.0 features, users generally performed similar numbers of edits. We believe this was due to users focusing on only one type of collaborative action (editing), and each user tried to contribute equally to the group project, so users each had to perform similar numbers of edits. On the other hand, in the Spring 2012 semester when users exploited the Web 2.0 features, we observe that editing behavior shifted to where only a few users made the majority of the edits to the groups' reports, whereas other users contributed instead through the additional Web 2.0 features. Thus, it appears that the use of Web 2.0 features caused role diversification within the groups, where users contributed in different ways. For example, some users tagged keywords to summarize the report and organize it within the context of the other pages in the wiki, some users actively discussed page content through comments, and others carried out designated edits. Moreover, other users contributed more to the class in general by rating many pages within the wiki, rather than contributing to their group's page. Therefore, adding additional Web 2.0 features achieved our goal of increasing opportunities for participation by different users, which led to greater overall participation by users.

Furthermore, the increased diversification of collaboration in the Spring 2012 semester also resulted in higher quality collaboration than the less diverse Fall 2011 semester. Table 2 shows that the grades earned for the group reports were much higher in Spring 2012 than in Fall 2011. Additionally, the standard deviation in student grades was also much smaller in Spring 2012, indicating that the quality of reports was *consistently* better in Spring 2012. Therefore, *the increased use of the Web 2.0 features resulted in not only* more *active collaborative activity amongst users, but also higher* quality *collaboration, thus benefiting the wiki system and users*.

Use and Effect of Intelligent Features

Next, we analyze the use of intelligent features by users only during the Spring 2012 semester (since these features were not available during Fall 2011). These features encourage the user to explore the other pages within the wiki by either directly recommending such pages or indirectly helping the user find related pages by organizing pages with similar keywords. To evaluate the impact of these effects, we present per user the number of such recommendations followed and the number of pages viewed in Figs. 1d and 1f.

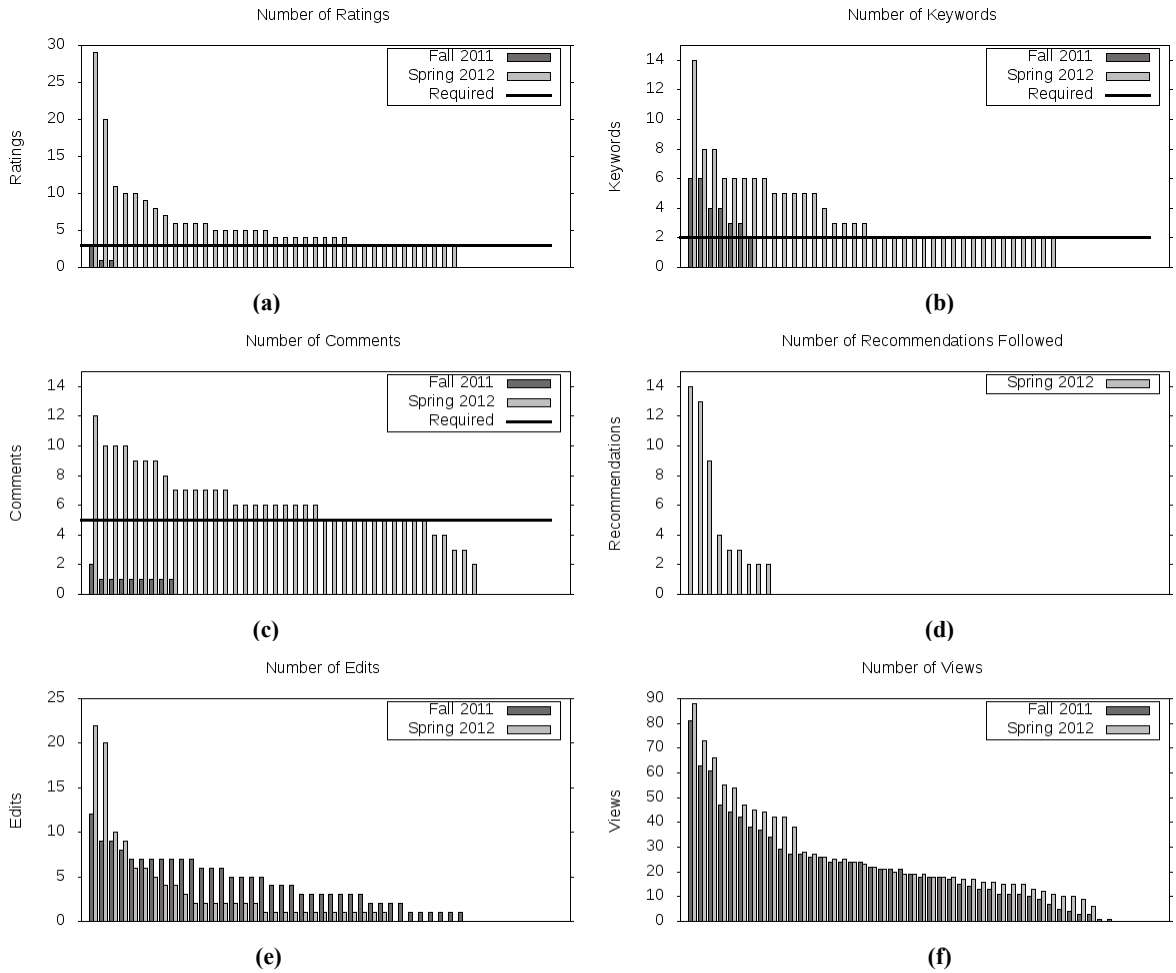

Figure 1. Ranked Ordering of Activity Counts for (a) Ratings Made (b) Keywords Tagged (c) Comments Posted (d) Related Page Recommendations Followed (e) Pages Edited (f) Pages Viewed
Note: the horizontal black lines in (a)-(c) represent the number of activities required for Spring 2012

Table 2: Grades Earned for Group Reports

	Fall 2011	Spring 2012
Mean	87.6944%	96%
Max	100%	100%
Min	72%	92%
SD	7.7527%	2.7756%

First, usage of this intelligent feature did *not* follow quite the same trend as the Web 2.0 features in Fall 2011. Specifically, despite the fact that in both cases the use of these features was not required, we observe that a *larger number of users* exploited the recommendations made by the system in Spring 2012 than used the Web 2.0 features in Fall 2011, and users did so *more frequently* as well. This result indicates that impactful, sustained use might be easier to achieve for intelligent rather than Web 2.0 features. Furthermore, such use could be enhanced through increased awareness of these features. Particularly, recommendations were made in an unobtrusive side panel located near the bottom of a page; with better visibility, this feature could become more useful to more users, similar to the effect we observed for required Web 2.0 feature usage.

Additionally, we observe that the inclusion of intelligent features positively affected the total viewing behavior of users. Most importantly, we note that the least active users (in the tails of the viewing distributions) viewed a higher number of page views in the Spring 2012 semester that included the intelligent features. This implies that including intelligent features encouraged users to more actively participate in the wiki-based activities by viewing more pages. This result could be due to the system making it easier for users to explore the collaborative knowledge stored within the wiki system, thereby lowering the costs of entry by the least active users.

Relationships Between Features

Finally, we analyze the relationships between the use of the different types of features and with the quality of collaboration. We consider the correlations between activity counts from each feature type and the correlation

between activity counts and grades. These results are presented in Tables 3 (Fall 2011) and 4 (Spring 2012). We highlight the results found to be statistically significant at the 0.01 and 0.05 significance levels.

In Table 3 describing the Fall 2011 semester where few students made use of the Web 2.0 features, we observe that a significant, positive correlation existed between the keyword tagging and page view and edit actions. Thus, the few students who used the advanced keyword tagging feature were active users within the wiki, indicating that including this feature didn't boost participation by inactive users, but was instead an additional way for active participants to collaborate. On the other hand, students who rated pages were also significantly likely to leave comments, indicating that a *second type of participants emerged*: students who offered feedback on pages, but didn't contribute additional content to wiki pages. Unexpectedly, the students' grades were not significantly correlated to any of the particular actions, indicating that even students who performed many actions (especially viewing and editing) did not necessarily achieve high grades for their reports, so the quantity and quality of wiki-based activity were *unrelated*. All other activities were not significantly correlated.

In contrast, in Table 4 we observe additional significant, positive correlations for the Spring 2012 semester. First, usage of all of the Web 2.0 features was highly correlated. Thus, using some features might have helped influence the use of others, which could be beneficial with assisting the system to reach "critical mass" of their usage and boost overall participation. Second, usage of the Web 2.0 and intelligent features was also highly correlated. That is, *users were more likely to use any of the advanced features once they used one of them.* Finally, we also observe several significant, positive correlations between user actions and their grades. This indicates that, unlike in the Fall 2011 semester, users who performed larger *quantities* of collaboration were also likely to achieve higher *quality* collaboration. Therefore, we have more evidence that increased participation through the inclusion of Web 2.0 and intelligent features led to better collaboration between users.

Table 3: Correlations between Activity Counts and Grades for Fall 2011 Note: ** = p < 0.01, * = p < 0.05

	View	Edit	Comment	Keyword	Rating
Edit	**0.7250****				
Comment	0.1745	0.1144			
Keyword	**0.3474***	**0.3413***	0.2753		
Rating	0.0964	0.2505	**0.2888***	0.0893	
Grade	0.0964	0.0141	-0.1411	0.3268	-0.3224

Table 4: Correlations between Activity Counts and Grades for Spring 2012 Note: ** = p < 0.01, * = p < 0.05

	View	Edit	Comment	Keyword	Rating	Rec.
Edit	**0.7531****					
Comment	**0.5514****	**0.3870***				
Keyword	**0.6061****	**0.4764****	**0.5726****			
Rating	0.1798	-0.0344	**0.3829***	**0.3336***		
Rec.	**0.3714***	0.1391	**0.4867****	**0.5322****	**0.3819***	
Grade	**0.4724***	**0.4268***	0.1650	0.1906	-0.1137	0.2050

Discussion

Based on these results, we finally evaluate our proposed hypotheses for our research study and begin to answer our research questions. First, we found support for hypothesis H3 because we observed that the inclusion of intelligent features led to an increase in the number of pages viewed by both the most and least active users in the system. Thus, recommending related pages and organizing pages by extracted keywords from the page content led users to explore the shared collaborative knowledge stored within the wiki, (1) boosting participation by less active users, and (2) potentially improving the individual knowledge of users after reading those pages.

Second, we found evidence both in favor of and opposing hypotheses H1, H2, and H4. We observed that simply including Web 2.0 features did not result in their usage (in Fall 2011), and thereby did not affect collaboration. However, once usage was encouraged through minimum requirements (in Spring 2012), not only were the features used more frequently, but their usage *often exceeded the requirements*. This led to (1) increased amounts of collaboration between users, supporting H1, (2) a diversification of roles in the collaboration process, supporting H2, and (3) increased quality of collaboration through higher grades earned, supporting H4.

Overall, with respect to studying wiki-based CSCL, we draw the following primary conclusion:

> *Including advanced (e.g., Web 2.0 and intelligent) features to support and promote active participation and collaboration amongst student users of wiki-based systems is valuable and can lead to higher quality collaboration, but must be **appropriately** encouraged.*

Specifically, such encouragement does not simply mean imposing minimum requirements for collaboration as in our study and considered elsewhere in the literature (e.g., Ebner et. al, 2008). Instead, such encouragement could possibly arise through *improved interface design*, such as better highlighting the existence and benefit of

such features. Moreover, *increased education* of the use of the interface could also encourage more advanced feature usage. Our users were simply assigned their projects with little to no education in the usage of the wiki tool or more than a brief introductory text explaining its features. Finally, periodic pop-ups or other *encouragement from the system itself* could also lead to increased usage of advanced features and the resulting benefits of more active collaboration. This last approach has been effective in other collaborative systems to encourage users to participate (Wash & Lampe, 2012). In the future, we plan to study these potential methods of encouraging users to participate in order to promote more active and effective collaboration amongst users and reach a "critical mass" where sustained active collaboration benefits both the system and its users. We also intend to add surveys and possibly interviews to our data collection (1) to better understand the interplay between student knowledge, technology experience, and motivation with our advanced software features and (2) more precisely measure increases in student learning (e.g., assimilation and accommodation, Cress and Kimmerle, 2008).

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