Augmenting Classroom Participation through Public Digital Backchannels

Honglu Du, Mary Beth Rosson, John M. Carroll
College of Information Sciences & Technology
University Park, PA, USA
{hzd106, mrosson, jcarroll}@ist.psu.edu

ABSTRACT
An emerging trend in classroom technology research is the use of computer mediated communication (CMC) tools in classrooms to encourage students' in-class participation. As part of this research thread, we have been investigating the potential of *public digital backchannels* for building feelings of community among students in university courses. We designed, deployed and evaluated such a tool in a 15-week field study of two undergraduate classes. We found students found using public backchannel during the class is of little distraction, that teachers' attention to the content posted on the channel influence students' tendency to use tools of this kind. Further, we found that the relevance of the content shared is predictive of students' use of ClasCommons in the classroom; these feelings in turn are related to students' perceptions of self-efficacy, collective efficacy and course-specific social support. We also analyzed the content posted in the public backchannel and considered the benefits and drawbacks of the public digital from both students' and teachers' perspectives. We conclude with suggestions for improving the design and deployment of course-related backchannels.

Categories and Subject Descriptors
H5.3. Group and Organization Interfaces: Web-based interaction.

General Terms
Design, Experimentation.

Keywords
Backchannel, sense of community, public display.

1. INTRODUCTION
In many college classrooms, students are passive spectators. The professor arrives and gives a lecture; students learn individually by listening and taking notes. This model of teaching in classes is called the transmittal model whereby students learn by passively receiving knowledge from the teacher. However, according to social-constructivist theories of learning, knowledge cannot be simply pulled from textbooks or "poured" from teachers' heads to students' heads. Instead knowledge is constructed by engaging individual learners to actively apply prior knowledge when making sense of new information, allowing the new content to be further elaborated as knowledge embedded in their minds. Under this theoretical perspective, the knowledge construction process is influenced by the surrounding community in which a learner operates (i.e., her social context). In contrast to the transmittal model in which students are passive information recipients, the social constructivist model places students at the center of the learning process – they operate as active learners[1, 2]. Currently, active learning has been recommended as one of the seven principles for good practices in undergraduate education[3].

Many active learning techniques have focused on participation in a range of in-class activities like discussion, writing and talking. Class discussion (including discussion, debate, questioning, explaining, etc.) is often noted as a common and effective strategy for promoting active learning[3]. However, there is evidence that the typical university classroom setting includes obstacles for maximum effectiveness of active learning techniques like class-wide discussions. For example, it is common to find in university classes that (a) vocal students consume most of the scarce in-class discussion time; (b) the teacher acts as a "sage on the stage," controlling everything going on in the class; (c) some students may have negative feelings if they are called on by surprise; and (d) some students suppress their question until the end of the class.

In this paper, we present a design and empirical evaluation of a public digital backchannel discussion tool – ClassCommons – to encourage students' participation and examine students' sense of community over an extended period of time.

2. RELATED WORK
The term "backchannel" is used to describe a non-primary communication channel between speakers and listeners, through which feedback is given from listeners to speakers in unintrusive ways to show interest, attention and other reactions [4]. Examples of face-to-face backchannels are body language like eyebrow raising or brief requests for clarification (e.g., "What?") or confirmation (e.g., "Right."). Research has shown that backchannels are important for maintaining communication efficiency[5].

In classrooms, students can use backchannels to interact with the teacher in an efficient and unintrusive manner. For example students use backchannels when they nod their heads to show that they understand a topic being discussed or they shake their heads to indicate that they do not understand it, and the teacher may adjust his or her lecture based on such feedback. However as the size of audience increases, backchannels are harder to establish and the communication between the speaker and the audience loses quality. It is hard for a speaker to perceive multiple simultaneous feedbacks from different listeners; visual signals are quickly lost in a crowd [6]. As a result, speakers tend to focus only on a few audience members and their individual backchannels. In situations with a large audience (e.g., a large lecture class), it is common that just a few individuals engage actively in backchannel communications with the speaker.

GROUP'12, October 27-31, 2012, Sanibel Island, FL, USA.

In studies of computer-mediated communication, the concept of backchannel has been expanded to denote an online chat that runs in parallel to other communication activities. For example, while the instructor is giving lecture in the front, students may be using a backchannel to talk to each other at the same time using IM or an online chat room. Yardi reported an analysis of such chat logs and found evidence that the backchannel discussion supported peer-to-peer learning[7].

More generally, researchers and educators have explored a range of technology interventions that might facilitate interaction between the teachers and students in classrooms. While there are multiple researches on using backchannel to support audience participation in conferences[8], in this review, we only focus on related work in classroom settings. For instance, classroom response systems allow the teacher to present multiple choice or true/false questions; students can then respond to these with specialized handheld "voting" devices, perhaps resulting in a public display of aggregated results [9-11]. While such systems can increase class participation, they have drawbacks. First, they need special hardware, typically purchased by or provided for each student. Second, the teacher-student interaction is very structured and limited. The instructor cannot obtain a rich understanding of what students are thinking. Third, interactions occur only at the teacher's initiative. While a touted benefit of using these systems is to support students who are too shy to speak up in class, it is still the teacher who initiates the interaction. Students continue to be relatively passive actors who react to teacher-initiated issues.

Other text-based classroom technologies offer students an opportunity to engage in richer interactions with the instructor. Active Class uses PDAs for classroom communication: students can post text questions to the teacher during lectures, using a handheld device. A teaching assistant (TA) may respond to these questions during class, or the teacher may choose to address some questions. When this system was used in undergraduate computer sciences classes, the researchers found that it helped teachers get timely feedback from the students, overcame student apprehension in large classes, and enabled multiple students to ask questions at the same time[12].

Classroom Presenter extended the concept of a backchannel by allowing students to annotate a slide being discussed by the teacher; the resulting notes are publicly displayed in the classroom. A trial of this system found that it increased class participation in classes from multiple disciplines [13, 14]. The Harvard Live Question Tool allows students to submit answers to questions that are raised by the teacher; the answers are displayed publicly in the class. No formal evaluations have been conducted to study the impact of this tool, although it has been recommended by Educause as an effective way to encourage students' participation and students-teacher interaction[15].

Fragmented Social Mirrors (FSM) [6] is another tool that was investigated as a public backchannel in classrooms. Students can post messages during the lecture; they can also indicate whether the message is a question, or if they simply want the instructor to slow down. The message is projected on a separate screen in the classroom. The system was tested in 6 class sessions (3 of them used FSM and the other 3 did not use FSM) and found that FSM encouraged students' initiatives in classrooms.

The studies cited above have evaluated the effects of classroom backchannels, but only for a limited period of time (usually 1-2 class periods), leaving longer term impacts unknown. Also, it is not yet clear what factors may influence students' willingness to adopt such tools in their classes. Thirdly, although researchers have discussed the advantages of using public backchannels in classrooms, less attention has been paid to the potential problems with such technology. This study aims to fill these gaps in this field of research. The current research benefits from a long term implementation and deployment of a classroom public backchannel tool in two classes. We seek to find the answers to questions including the factors influencing students' adoption of this kind of tool, its long term impact on students' sense of community, and the benefits and drawbacks of tools of this kind in classrooms.

3. CLASSCOMMONS

The design of ClassCommons is drawn from a general design concept wherein people are offered a common interaction space to interact with one another virtually while in a shared physical environment. Thus the design requirements for ClassCommons are relatively simple: accept input from students, present students' submitted content in a controlled fashion, and manage the display of this input. The ClassCommons system accomplishes this with three basic components; there is a client device (any device with web browsing capability can be used, e.g., web-enabled mobile phones, laptops), a server and a large public display.

The goals of ClassCommons are similar to the impromptu backchannel activity studied by Yardi [7], but the tool differs in the following respect: the backchannel discussion is public, whereas in the Yardi study students simply talked to each other without any teacher involvement. In fact, ClassCommons emphasizes the public nature of the chat by integrating a large display visible to all.

Previous studies of ClassCommons found that students used ClassCommons to socialize with peers, make suggestions for course changes, share information, and seek help, facilitating feelings of community[16, 17]. The system used in this study is an improved version of the earlier prototype. Usability bugs (e.g., display readability) were addressed and new features were added, including: a) options to post emoticons, videos and photos; b) a liking function; c) threaded interaction; and d) public anonymity and private accountability (PAPA). Further, the previous studies were short term study and it was only evaluated in 2 class periods, leaving the long term impact unknown.

Any device with access to the Internet can be a client. To contribute, students log in to a posting website (Figure 1) with their university account and credentials. Students can post text messages, images and Youtube videos from the client interface. Students can choose to post with their real name or enter an alias when posting. The messages students post are shown on the public display in the front of the classroom. Students can reply to messages already posted on the client interface and can "like" individual messages. The number after Like on Figure 2 indicates how many students have liked that message.

The messages are displayed in real time on the public display, viewable to all the students as well as the teacher in the classroom. In the current version, messages are displayed in a "First In First Out" (FIFO) fashion, namely the messages posted earlier are displayed first. The most recent message appears at the top the public display with a red new icon in the front. Whenever a new message is posted, older messages will be pushed downward. If a video or image is posted, a thumbnail of the video/image will be displayed at the right side of the display. The instructor can then decide whether to play the video or not in the class. Figure 2 shows the layout of the public display.

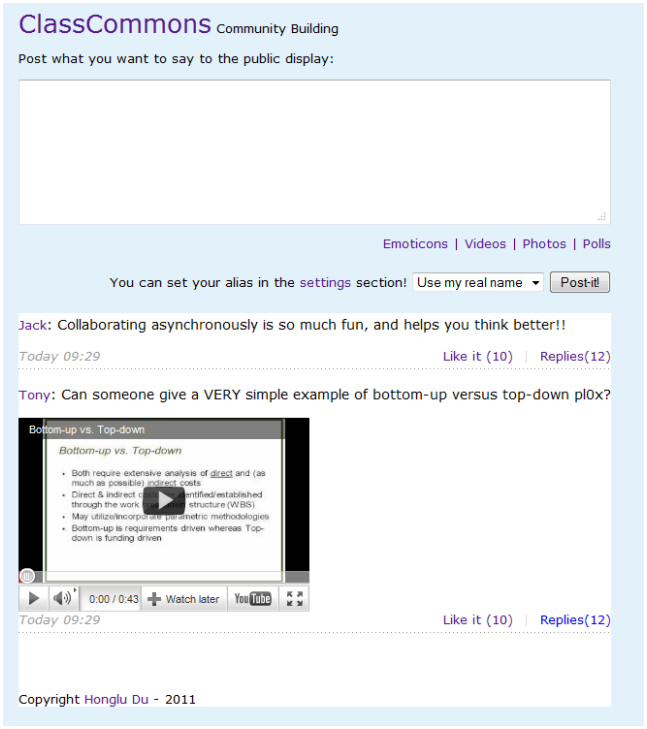


Figure 1. Client Interface of ClassCommons

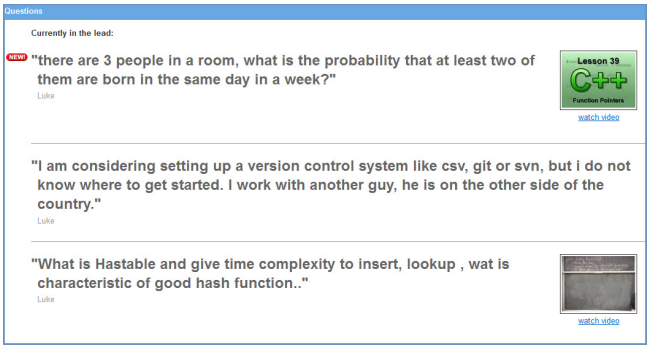


Figure 2. Public display view of ClassCommons

Public Anonymity and Private Accountability (PAPA): The system implements a policy known as public anonymity and private accountability (PAPA). Students can choose whether to use their real name or enter an alias when posting a message. However if a student uses an alias, the teacher can still discover the identity of the sender. This was implemented because findings from a previous study[17] indicated that students who are shy are concerned about having their real name displayed on the public display. But on the other hand, complete anonymity could lead to more mischief. The PAPA feature allows students to choose public anonymity with respect to their classmates but still be held accountable by their teacher.

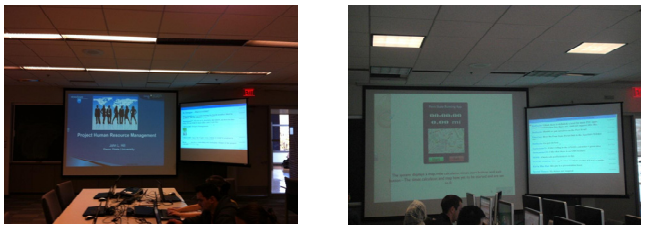
4. THE FIELD STUDY

ClassCommons was used in 2 classes for 15 weeks in the fall 2011 semester, from Aug.29th to Dec. 9th, in a large university in Northeast America. One class was about project management (PM) and had 67 students, with 16 females and 51 males. PM met twice a week on Mondays and Wednesdays for 75 minutes each time. The teacher for PM was a senior instructor teaching this course for the third time.

The second class was about human computer interaction (HCI) and had 50 students, with 7 females and 43 males. HCI met three times a week on Mondays, Wednesdays and Fridays for 50 minutes each time. The instructor of this course was a junior instructor teaching HCI for the first time.

Students in both classes were juniors and seniors, and 4 males and 1 female were members of both classes. Both classes are required courses in the undergraduate curriculum. Students were offered up to two extra credit points for participating in the study; this offer was made at the start of the semester when they were invited to complete a background survey. The amount of extra credit they received was determined by their level of participation (the number of messages posted). Students were not required to participate in the research study to gain access to ClassCommons.

We chose these courses as testbeds for ClassCommons for two reasons. One is that both courses are mid- to large-size classes where "feelings of disconnectedness are common among students" [18]. Thus we hoped that building a sense of community within students would improve the quality of students' educational experience. The second reason was more pragmatic – these two courses were taught in classrooms where every student has a laptop to use during the class, making it possible for every student to interact with ClassCommons if/when desired.



(a) PM Class (b) HCI Class

Figure 3. ClassCommons in the 2 classes

Figure 3 shows the setup of ClassCommons in the 2 classes. The larger public display on the left is used by the teacher to project lecture slides; the second smaller public display on the right contains the content posted through ClassCommons. The public display was 5' (width) x 6' (height); pilot testing ensured that the font size used was legible from every location in the class.

The instructors chose to use different policies regarding the use of ClassCommons in their classes. The PM instructor allowed no posting of entertaining messages or any message unrelated to class content; in contrast the HCI instructor had no constraints and welcomed any content. This difference in usage protocol had consequences for how students used ClassCommons during the semester and we will report this in the result section.

5. DATA COLLECTION

We used multiple methods for data collection, including a pre-survey (before using ClassCommons), a mid-survey (about half way through the semester) and a post-survey (at the end of the semester). We also archived the ClassCommons usage logs, conducted a small set of interviews and recorded informal observations. In the pre-survey, we collected a set of background characteristics for participating students as well as initial values for perceived sense of community. We used the subsequent surveys to assess potential changes in sense of community as well as to examine students' perceptions about the system and about their course efficacy as individuals and as a class. We now describe the measures in more detail.

Pre-survey. Before ClassCommons was introduced, students were invited to complete a background survey. They were offered extra credit at this point for agreeing to serve as research participants (all students were able to use ClassCommons regardless of their participation in the evaluation process). We gathered information about participants' interests in interacting with the instructor and other students and their experiences with using social media tools like Facebook, Twitter and online discussion forums were gathered. We used 7-point Likert scales from prior research to measure personal variables, including **Extroversion**, classroom anxiety (**CAnxiety**) and public speaking apprehension (**PApprehension**) [19-21].

Because we were particularly interested in how ClassCommons might affect students' feelings of connectedness with one another, we measured *sense of community* at multiple points including prior to ClassCommons use (**PreSOC**). For this construct we adapted an existing scale of seventeen items [21, 22]. Example items were: "I feel that I am encouraged to ask questions in this class"; "I feel that I belong when I am in this class"; "I have a say about what goes on in this class"; and "I feel connected to the class", covering the four dimensions of sense of community, namely fulfillment of learning need, membership, influence and shared emotional connection[22]. We assessed scale reliability with Cronbach's alpha coefficient, which was 0.88 for the PreSOC data. According to[23], a value of over 0.5 is acceptable for a scale intended to measure a single psychological construct.

Mid-survey. At the beginning of the seventh week, students were invited to complete another survey, where we again measured sense of community (**MidSOC**). We included other measures in this survey as well but for lack of space do not report further analysis of these data.

Post-survey. At the end of the fifteenth week, students were invited to complete another online survey. Once more we assessed sense of community (**PostSOC**).

We probed reactions to the messages that had been posted: the relevance of the content (**Content Relevance**); the extent to which the student feels s/he can learn something new from the messages (**Learn New Information**); and general interest (**Interest**). These three judgments were made on a 7-point scale from 1: not at all to 7: very much. We also asked students to which degree they felt that ClassCommons was a distraction in the classroom (**Distraction**). This judgment was made on a 5-point scale from 1: Not distracting at all, to 5: very distracting. Finally, we used two open-ended questions to probe students' general feelings about ClassCommons, namely what they liked most about and least about it.

The post-survey also asked students to report how much attention they felt their instructor had paid to the messages posted on ClassCommons during the semester (**Teacher Attention;** from 1: none to 5: very much). At this point, we also gathered self-reports about **Use of ClassCommons**. We did this with three 5-point Likert scale items scale (Cronbach's alpha= 0.74). The questions were "How often did you glance at the public display for ClassCommons in the class?"; "How often did you check the ClassCommons system on your own workstation in the class?" (1: Never, 5: Very often) and "How many messages did you read?" (1: I did not read any of them, 5: I read every comment).

To investigate relationships between ClassCommons and class performance we assessed students' feelings of efficacy in the class, both for themselves and as a collective. **Self-efficacy** is the belief that one is capable of performing in a certain manner to attain a certain set of goals[24]; it is a strong predictor of people's actual performance[25]. In this case we developed four 7-point Likert scales to assess self-efficacy in the context of the classes the students were taking (Cronbach's alpha= 0.73). Example items were: "I can have an impact on class discussions, even though I am only one member in a relatively large group of students."; "Even though I may have trouble at first, I can master the concepts that come up in this course".

Collective-efficacy is similar to self-efficacy but refers to beliefs about joint endeavors and joint outcomes[26]. It was measured using six 7-point Likert scales that we designed for this study (Cronbach's alpha= 0.90). Example items were: "OUR CLASS can ensure that all members' ideas are considered, even if one idea does not seem to fit"; "OUR CLASS can ensure that everybody gets a chance to contribute to discussions, even though we are not all comfortable speaking up".

Finally, we included a measure of **Social support** to investigate how students' class-specific social networks might relate to the other variables being assessed. Social support is defined as feeling that one is cared for by and has assistance available from other people and that one is part of a supportive social network. Students' feeling of social support was measured using six 7-point Likert scales developed for this purpose (Cronbach's alpha= 0.81). Example items were: "If I wanted to do some extra studying for a quiz, I would have a hard time finding someone to study with me"; "If I wanted to form a small reading group to study for this class, I could easily find others to join me".

Log data. All the messages students posted to the public display were logged on the server. Log data include the messages, the images, the videos and the Likes students voted.

Interviews. At the end of the semester, 10 semi-structured interviews were conducted to understand students' and teachers' (the instructors and the TAs) feelings about using ClassCommons. Six students, two instructors and two TAs were interviewed. The interviews lasted from 20 to 30 minutes. Five of the students were in both classes; one was enrolled in HCI only.

We selected the dual-enrolled students because they could provide us a rich understanding of possible differences between the two classes, including whether and how such differences might have influenced their use of ClassCommons. In addition, these 5 students used ClassCommons to different extents. Some posted more than 50 messages while others posted fewer than 10. The sixth student was selected from HCI because he used the system frequently and in many different ways.

During the student interviews, we asked about motivations for using ClassCommons, perceptions of benefits and drawbacks of ClassCommons, and the differences if any that they perceived between PM and HCI (except for the sixth student); we also asked for suggestions about how to improve ClassCommons. In the interviews with the instructors and TAs, we asked about perceived benefits and drawbacks of ClassCommons.

On-site observation. Observations were carried out during the class. One researcher was in the classroom observing students' use of this system during the whole semester.

6. RESULTS

We gathered a variety of data, much of it obtained through surveys. In some cases we repeated scales from one survey to the next. In presenting our findings, we first give an overview of

measures from the pre-survey and post-survey that form the basis of the multivariate analysis reported later; we also summarize the ClassCommons usage data. We then provide a more detailed discussion of differences between the PM and HCI class, exploratory regression analyses of ClassCommons use, and a content analysis of the messages contributed by students.

6.1 Overview

ClassCommons was used in both classes from for 15 weeks. The first class session was used for familiarization with ClassCommons, so messages posted on that day are not included.

Students rated their use of social network sites like Facebook, micro-blogging like Twitter and online forums (1: never use, 2: few times a year, 3: few times a month, 4: few times a week, 5: everyday, 6: several times a day). Most students used social network sites (SNS) like Facebook often, with 76.3% of the students in PM class and 88.5% of the students in HCI class reporting that they use Facebook at least once a day. In contrast, micro-blogging is not as popular, with only about 20% of the students using a tool like Twitter every day (PM: 20.4%, HCI: 22.9%). Reported use of online forums was even more rare.

Table 1 summarizes variables measured in the pre-survey that were used in the analysis reported in Section 6.3. As the means suggest, students reported being moderately interested in having interactions with the teacher and other students (a bit higher than the neutral point of 3.0 on a 5 point scale). With respect to the personal variables, the mean values suggest that these students are somewhat extroverted (just above the mid-point of the 7-point scale), not particularly anxious about being in the classroom, and a bit apprehensive about public speaking. The two classes do not differ on these variables.

Table 1. Analysis variables measured in pre-survey

Variable	Class	Mean (S.D.)
Interest interacting with teachers	PM	3.69(0.73)
	HCI	3.77(0.65)
Interest interacting with students	PM	3.75(0.65)
	HCI	3.89(0.68)
Extroversion (index of 7 items)	PM	4.72 (0.44)
	HCI	4.68 (0.49)
Class anxiety (index of 20 items)	PM	3.26 (0.43)
	HCI	3.00 (0.40)
Public speaking apprehension (index of 6 items)	PM	4.00 (0.65)
	HCI	4.04 (0.91)

N=59 for PM; N=49 for HCI
The first two variables were assessed on a 5-point scale, the final three on a 7-point scale

Table 2 summarizes students' self-report of ClassCommons use, gathered at the end of the semester in the post-survey. The first three items in the table refer to students' ratings of the content they have been viewing on the public display over the semester (i.e., did they like using it, is the content relevant, and can they learn new things from the posts). In general these ratings were in the positive direction (collapsing across classes, each rating is significantly greater than the neutral value of 4.0, $p<.001$). At the same time, we can begin to see some possible differences between the two classes, with the HCI class reporting a higher value for Interest in ClassCommons than the PM class ($t(92)=2.06$, $p<.05$). A similar difference emerges in the judgments concerning how much attention the instructor paid to the system ($t(91)=4.0$, $p<.001$). Although we have no other measures of teacher involvement in ClassCommons, it seems that at least from the student perspective there is a difference across classes. The informal notes taken by the first author while in class were also consistent with this impression.

Table 2. ClassCommons use measures from post-survey

Variable	Class	Mean (S.D.)
Interest*	PM	4.89 (1.16)
	HCI	5.38 (1.10)
Content Relevance	PM	4.66 (1.14)
	HCI	4.48 (1.24)
Learn New Information	PM	4.98 (1.09)
	HCI	5.10 (1.21)
Distraction	PM	2.13 (0.76)
	HCI	2.34 (0.98)
Teacher Attention**	PM	2.94 (1.0)
	HCI	3.75 (0.9)
Use of ClassCommons (index of 3 items)	PM	3.16 (0.63)
	HCI	3.42 (0.83)

N=53 for PM; N=41 for HCI. The first three variables were assessed on a 7-point scale, while distraction, teacher attention and system use on a 5-point scale
** difference between classes is significant, $p<.05$*
*** difference between classes is significant, $p<.01$*

Students did not find using ClassCommons in the class was distracting (collapsing across classes, each rating is significantly greater than the mid -point value of 3.0, $t(92)= -8.87$, $p<.001$). On the 5 point scale, students felt that using ClassCommons was of little distraction to them.

We also asked more directly for ClassCommons use reports. As explained earlier, the index in the table combines students' estimated frequency (on a 5-point scale) of glancing at the public display, checking in on the system using their own machine, and reading messages. The average value is greater than the mid-point of 3.0 ($t(92)=3.6$, $p<.001$), but while there is a trend for these self-reports to be higher for the HCI class than the PM class, this difference falls sort of significance ($t(91)=1.67$, $p<.10$). Nonetheless, in combination with the contrasts of liking and teacher attention, these data suggest that system use and acceptance varied across the two classes. We will return to this point later.

Table 3 summarizes psychological variables measured in the third survey. A scan of the means suggests that perceptions of social support from other students, and both self- and collect-efficacy are moderately high but that they do not vary across classes.

Table 3. Social support and efficacy from post-survey

Variable	Class	Mean (S.D.)
Social Support (index of 6 items)	PM	5.41 (1.08)
	HCI	5.23 (0.72)
Self-efficacy (index of 4 items)	PM	5.57 (0.75)
	HCI	5.56 (0.82)
Collective-efficacy (index of 6 items)	PM	5.48 (0.86)
	HCI	5.45 (0.96)

The social support and efficacy scales were assessed using a 7-point scale

Finally, ClassCommons usage logs provided good evidence of participation, though again this appears to vary across classes. In PM, 47.8% of the students (32 of 67) in PM posted messages in the system at least once, while 84% of the students (42 out of 50) in HCI did so; a chi square test of these frequencies confirms that the pattern is significant ($\chi^2(1,N=117) = 16.18$, $p<.001$). In total 641 messages were posted and 254 Likes were voted. Table 4 shows the detailed use of ClassCommons. Note that the teaching assistant in both classes contributed messages, generally in re-

sponse to questions. Again the classes differed in this, with the TA contributing almost 20% of the messages for PM but just over 5% for HCI.

Table 4. The use of ClassCommons in PM and HCI

Class	Participation	Messages (Students/ TA)	Likes	Sum
PM	47.8%	84 (65/16)	95	179
HCI	84.0%	557 (527/30)	159	716

Recall that ClassCommons supports posting of photos and videos in addition to text. Across both classes, 76 images were posted, but video content was not common in students' postings; only five video clips were posted, and all of these were in HCI. Table 5 shows the details of the distribution of multi-media posts.

Table 5. Photos and videos posted in ClassCommons

Class	Photos	Videos	Sum
PM	1	0	1
HCI	75	5	80

Students in both classes made heavy use of the PAPA option (using an anonymous handle when posting), but use of this feature was more common in HCI than PM. In the HCI class, 77.9% of the messages were posted under an alias and in the PM class, 60.7% of the messages were posted under an alias ($\chi^2(1,N=592) = 10.00$, $p<.05$, only messages posted by students were included in this analysis). That is, students in HCI class tended to post using an alias more often than students in PM.

In general, students enjoyed using ClassCommons and the majority of students in both classes would like to use ClassCommons in other classes. In the post-survey, we asked whether they would like to use ClassCommons in future classes. 88.68% of the respondents (47 out of 53) in PM and 92.68% of the respondents (38 out of 41) in HCI indicated that they would like to do so.

6.2 Contrasting the Two Classes

One pervasive result concerning ClassCommons use is its differential impact on the two different classes: students in the HCI class used the system more and used it in more ways; they also reported that they liked it more and that their instructor paid more attention to the messages being displayed. To better understand why these differences may have emerged, we interviewed students, teachers and TAs for opinions about these differences. The fact that five of our interviewees had been in both classes was particularly useful in probing for explanations. In reviewing their comments, three themes emerged: the nature of the course topic, the amount of attention the teacher paid to the content posted on ClassCommons, and the instructors' teaching style.

The richness of the course material and the difficulty of the subject played an important role. Compared to the PM class, students in the HCI class found the course material to be more interesting and therefore more likely to evoke backchannel comments. For example, S1 (Student1) said *"I think PM, the subject is pretty dry. It is not interesting, and then human computer interaction (HCI) is a lot more interesting, a lot more fun. There is a lot more human touch to that class"*. The TA for PM commented *"It might be the material of PM is pretty straightforward. You just store the knowledge and learn. Maybe if you have a math class or something, where you have to apply what you learn to solve problems, students might use it more (to ask questions)."*

A second factor was the attention the teacher paid to the messages on ClassCommons. We reported earlier the survey finding that students in HCI reported that their instructor paid greater attention to the backchannel than those in PM. In the interviews, students opined that their instructor's acknowledgement of ClassCommons messages encouraged them to use it more. S5 mentioned that *"I think it (the message) is more acknowledged in HCI. The professor kind of actually looked up at the public display. The questions are usually acknowledged, read and answered….(In PM class), he did not really look up at the display much*". S4 said that *"The fact that the professor acknowledges the display encourages student to use the display. They acknowledge the posts on ClassCommons, they address the questions on ClassCommons, and it makes it more useful, more popular"*. This combination of survey and interview data emphasizes the critical role of teacher attention in adoption and use of technologies like ClassCommons.

Finally, students are more likely to use ClassCommons in classes whose instructor adopts a more personal approach to teaching. For example, S2 said that "*(instructor of HCI) is very personal the way he teaches it. Whereas PM is much more of a big class, I found that it was more impersonal.*" S4 commented that *"In PM, the instructor seems stricter.*" The PM teacher was quite senior relative to the HCI teacher and this may have influenced their teaching style and students' subsequent reaction to and motivation to engage with them via the backchannel. In general, though, the backchannel is intended for relatively informal exchange, so it would make sense that professors who exhibit a more informal teaching style might encourage more participation.

6.3 ClassCommons Usage Model

To gain insights into how ClassCommons affected students' classroom experiences, we carried out a series of exploratory multiple regression procedures. Given the scarcity of past related work, our goal in this was not to formulate and test hypotheses but rather to build conceptual models of inter-related factors that might be used to guide future research. To increase the power of our analysis, we used the combined data from the two classes in all regressions. Because many of the predictor variables are correlated, we used stepwise regression; in this approach multiple dependent variables are used to predict a single outcome variable, and are added to the model only when they account for variance not already accounted for by other variables[27].

6.3.1 ClassCommons Usage Model

Several student characteristics were assessed and regressed on their starting Sense of Community (PreSOC). For example we expected that students' Classroom Anxiety might negatively impact their starting Sense of Community, whereas Extroversion would show a positive relation. As expected, the regression model for PreSOC revealed a significant positive relation of Extroversion ($p<.05$) and a negative relation of Class Anxiety ($p<.01$); no other student variables provided explanatory power in the model, which accounted for 39.5% of the variance.

A number of variables might influence students' use of ClassCommons. In Section 6.2 we discussed some of the differences between classes that seemed to play a role in this, but we also wanted to explore student variables, both in terms of their personal characteristics and their beliefs about the usefulness or interest of the ClassCommons system. For instance one would expect that students who believe ClassCommons provides relevant content would find themselves using it more. To investigate this we regressed the variables from the first model (PreSOC, Extroversion, and Class Anxiety) and the four system ratings (Interest, Content Relevance, Learn New Information, Distraction, see Table 2) on the ClassCommons use index. The resulting

model accounted for 36.5% of the variance and included positive relations of Interest (p<.01), Content Relevance (p<.05) and PreSoc (p<.05).

The third regression model considered the possible impact of ClassCommons use on Sense of Community. The system was designed to enhance students' feelings of community, so we expected a positive relation between use and felt community. To examine this possibility, we regressed the variables from the previous model (Interest, Content Relevance, PreSOC and PostUse) on PostSOC (in this model PreSOC is serving as a covariate, i.e. to control for individual tendencies in SOC). The resulting model accounted for 28.4% of the variance in PreSOC and included positive effects for PreSOC (p<.001) and PostUse (p<.05).

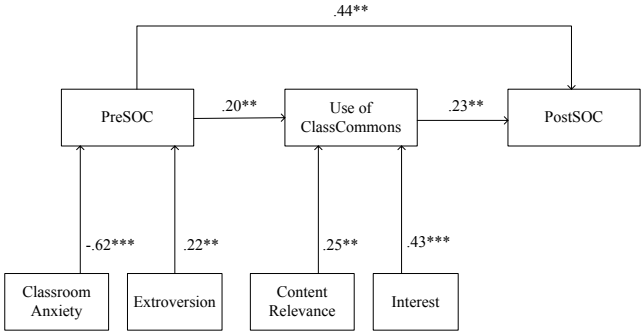


Figure 4. Path diagram relating ClassCommons use to SOC

Figure 4 combines the results of the three regression analyses in a path diagram. In the diagram the arrows show which measures served as independent variables in each model; the numbers on the arcs report the standardized beta or regression coefficient for each predictor. The model summarizes the three overlapping models: 1) classroom anxiety and extroversion predict PreSOC; 2)PreSOC, content relevance, and student interest predict use of ClassCommons. However, personal variables like extroversion, classroom anxiety or public speaking apprehension do not predict their use of ClassCommons; they may have an influence but it is indirect through their relationship with PreSOC.

Finally, students' PostSOC is predicted by their PreSOC and their use of ClassCommons. While we acknowledge that these models are based on correlations only, this pattern of results is consistent with our expectation that use of use of ClassCommons can help students feel more sense of community.

6.3.2 Broader Impact of Sense of Community

As a secondary analysis, we also wanted to explore the broader impacts that are associated with students' sense of community. In particular, we were interested in whether and how sense of community is related to students' self-efficacy, social support and collective efficacy in the classroom. We expected that high sense of community will be positively related to students' self-efficacy, social support and collective efficacy in the classroom.

Our data confirmed this. We found that PostSOC is significantly correlated with self-efficacy (r=0.58, p<.001), collective-efficacy (r= 0.60, p<.001) and social support (r = 0.60, p<.001). As above, we cannot argue for a causal interpretation. Given the large degree of collinearity in our data, further studies will be needed to tease apart these overlapping constructs.

6.4 Sense of Community

Students' sense of community changed differently in the two classes. Table 6 reports students' sense of community in both classes along the semester. A one-way within subjects ANOVA was conducted to compare the effect of time on students' sense of community in each class. In PM, there is a significant effect of period ($F(2,46) = 24.55$, $p < .001$). Bonferroni post hoc tests revealed significant differences in the scores for PreSOC and MidSOC (p<.001) and for PreSOC and PostSOC (p<.001). However there was no increase from MidSOC and PreSOC: Students' sense of community increased in the first seven weeks, but stayed at the same level until the end of the semester.

For the HCI class, there was no significant effect of time at all ($F(2, 23) = 2.69$, $p = .089$). Relative to the PM class, students' sense of community started out at a high value and stayed there. One possible contributing factor for the higher initial SOC is that the size of the HCI class was smaller than PM; perhaps the smaller size helps students to feel more coherent.

Table 6. Sense of Community across classes and time

Class	PreSOC	MidSOC	PostSOC
PM	4.41(0.61)	4.86(0.68)	5.0(0.75)
HCI	4.82(0.70)	5.00(0.72)	4.79(0.75)

Based on our data, we speculate that sense of community may have an asymptotic growth trajectory in university courses. More specifically, we propose that a value of around 5.0 (on a 7-point scale) may be an asymptotic value for this construct in this context, that is when the community in question is a group of students who happen to be taking a course together. Note that in Table 6, the initial SOC value for the PM class is the only one that is not close to this value of 5.0. While individual students may experience more or less sense of community in a classroom, it may be that few of them would ever feel a sense of community intensely enough to assign scale values of 6 or 7. This does not mean that the construct is not valuable for assessing feelings of "connectedness", but it may be useful to explore an alternative to the conventional SOC scale, perhaps one that is customized for the learning communities one could expect to emerge in a 15-week class.

6.5 Content Analysis

To understand how students' have used ClassCommons, we analyzed the messages posted in each class. We used a card-sorting technique to categorize the messages. Each message was read, and assigned a descriptive label. The messages were then clustered into similar groups. We clustered the messages into nine types: social, questions, TA response, report problems, logistics, comments, share info, counter spam and random messages. Examples of each category can be found in Table 7.

Social messages refers to the small talk that usually happened at the beginning or end of class. For example, students might post a message to greet one another, or to talk about the sports and news going on campus or around the world. ***Questions*** are messages that contain questions about the course. ***TA responses*** are the messages posted by the TAs, answering students' questions or making announcements. ***Report problems*** are messages posted to report the problems that students found in the class.

Logistics are messages to deal with logistical issues in the class, for example locating team members. ***Comments*** are the messages posted by students during the lecture, commenting on the things

Table 7. Examples of the messages by type

Message Type	Example
Social	"Hi folks."; "Class is starting! IM SO EXCITED"; "have a great weekend folks!!! Stay dry, and GO STATE!!!"; "Predictions for the score on Saturday? I say 45-7."
Questions	"Anybody here able to access their u drive?"; "Unjustified claims are bad, mmmkay?"; "anyone know if we are choosing something, or making something entirely new?"
TA Response	"We suggest you find problems that apply to broader audiences."; "You can use whatever presentation technology you choose." "Grades for 4 and 5 are up (unless we didn't get your assignment)."; "Both options are acceptable. Designing something completely new, or improving an existing system."
Report Problems	"One of the problems did not match up with what was discussed in class"; "Team 3 seems to be a combination of team 8 and 9... typo?"; "it's frustrating, I can't open any documents from my desktop or drives."
Logistics	"GROUP #16 WHEN YOU'RE DONE MEET IN BACK CORNER NEAR THE CLOCK"; "TEAM 10 can we meet in the front of the room today after class?"; "Currently looking for fourth member. Must be qualified, and like puppies. Inquire within."
Comments	"awesome presentations today!"; "This design is against man law.(commenting on a design discussed in the class)"; "Can't see the stock on the left machine (commenting on 2 vending machine designs)"
Share Info	"Here's the video which goes along with the Microsoft team's blog post about Windows 8 and improvements to Windows Explorer..."; "Hey everybody! I found some cool news related to interaction design. J.D. Power and Associates recently performed a user satisfaction study for several popular smartphones. Here's the link: …."; and Wikipedia links like http://en.wikipedia.org/wiki/Synesthesia'; "a great example of classical conditioning/pavlov's dog, http://vimeo.com/6217895"
Counter Spam	"Can you guys stop posting weird videos and pics?"
Miscellaneous	"derk-a-derrr"; "it's a tarp"

that the teacher just talked about. ***Share info*** message are ones that were posted by students who meant to share information to the whole class. Messages of this kind usually contain a URL link to some webpage from the Internet. ***Counter spam*** messages were ones that were intended to stop other students from posting random messages. ***Random*** messages are ones that were posted during the lecture, and have nothing to do with the class. The differences between comments and share info messages are that share info messages are ones that have new information, while the comments are just messages posted by students in response to the lecture, without obvious new information inside.

Given the other differences between the two classes, it was not surprising to see differences in the types of messages posted; this can be seen in Figure 5. Students in PM made more focused use of the tool than students in HCI; they tended to use it to ask questions, report problems or for class logistics. And because students posted such questions, the TA posted more (responses) in PM than in HCI. Students in HCI often used the tool to make comments, and share information. There were also more random messages in HCI than in PM.

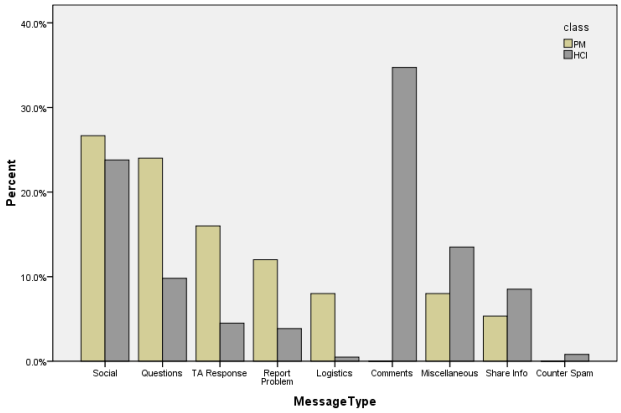


Figure 5. Content Analysis of the Messages Posted

6.6 ClassCommons Benefits and Drawbacks

To understand the tradeoffs of using ClassCommons, we asked students what they liked the most and the least about ClassCommons in the mid and post surveys. We also asked students and the teachers and the TAs similar questions during the interviews. These qualitative data helped us gain deeper insights into the benefits and drawbacks with using ClassCommons, from both the students' perspective and the teachers'.

Students felt that the benefits are that **a) they can easily ask questions and get quick responses from the TA.** For examples, students mentioned that *"What I liked best is that at any time I can post a question and get a timely response from a TA"; "It makes asking questions in lectures feasible without disrupting the flow of class. Often times I will not want to interrupt the professor, and hold off on asking my question, only to later forget what my question at the time was"*; *"I like the fact that I'm able to interact with others and the instructor without yelling across the room."* **b) they can interact with other students and provide peer support and learn new information from each other.** For example, students said that *"It's a great way to interact with other students during class times without being disruptive to the teacher. You can ask quick questions to other people and get a timely response"; "I like the ability to post a question and have it answered immediately by my peers who have the extremely unique perspective of being in the exact same position in the course"; "The technology and idea of it is pretty cool. I do learn things about the class from looking at the message board"*, and **c) it makes the class experience fun.** *"It was interesting to see what the other students were thinking"*; *"It is a fun and more forward approach to learning"*.

Students' only perceived downside with using ClassCommons is that the alias feature encourages people to post irrelevant content which is distracting to the class. *"The first few weeks, the messages almost always consisted of distracting and/or vulgar content, probably because submissions were anonymous. If real names were used, ClassCommons might work better in classes"; "Alias encourage distracting comments"* and *"People like to be anonymous in order to post stupid comments and things that don't matter, this can get annoying."*

From the teacher's perspective, the instructors felt that ClassCommons is a social media service that is more relevant to the class than Facebook. The instructor of HCI commented that *"During the class, many students spend a lot of time on Facebook, which is irrelevant to the class. I would rather like students*

to spend that time on ClassCommons, which is more relevant to the class than Facebook. We can use ClassCommons to replace Facebook in classes." For the instructor of PM, he felt that the public display seems to make the class more coherent. He said that *"I think this class as a whole, seems to be somehow more coherent than before. It made a community of interest around that system and that community of interest might help them. It gave them all a common thing to focus on."*

The concerns the teacher had with ClassCommons were the anonymity issue and the possibility of causing embarrassments for other students. For the anonymity issue, the teachers voiced a concern similar to the students. For the embarrassment issue, the instructor of HCI mentioned that *"Sometimes I will ask students to make presentations about their group project in the class. I remembered that one time when a student was presenting, he made some mistakes and some students pointed that out directly on ClassCommons. I felt that this could embarrass the student who is presenting"*.

6.7 Improvements

Finally, in the post survey and the interviews we asked students and the teachers for their opinions about how to improve ClassCommons. Students' feedback focused on two aspects: they wanted the instructors to improve how they use ClassCommons; and they had some detailed suggestions about improving the system. Among these two, students felt that addressing the first aspect is more urgent than the system enhancements.

Students commented that they wanted the instructor to improve the way that they used the system. More specifically, they suggested that the instructor should pay more attention to the messages posted on ClassCommons, instead of just leaving it for students to interact with other students. For example, S1 said that *"The only thing I would say is to pay attention to it more... and answer the question more quickly or like pause every 30 minutes to look at it"*. S5 commented that: *"I think if they can look at it, acknowledge the comments and answer any questions that is up there would help. Mostly, just acknowledging is the important part."* S6 also suggested that *"Teacher could ask questions, students respond and the teacher acknowledge them. That would be something that would be beneficial. I think it is a good way to promote engagement and excitement"*.

As to more detailed system level improvements, it is suggested that **a)** there should a discrete way to notify the professor when new messages are posted. S4 suggested that "Maybe there was a discrete way that the professor could be notified that something has been posted. Most of the time, the professor is lecturing, walking around the classroom, not really paying attention to the classroom display, until the end." **b)** it would be useful if users can highlight important questions on the display. For example, the instructor of PM suggested: *"Please highlight the important questions on the display so that I can easily identify them and address them accordingly"*.

These comments reinforce our earlier discussion of the important role teachers' attention plays in encouraging students' use of the system. Students wanted the instructor to know their concerns and wanted to get the instructor's attention.

7. DISCUSSION

Our study of ClassCommons can be judged a success, given that 90% of the students would like to use ClassCommons in future classes. We feel that three of the most important lessons we have learned from this experiences are that a) teacher's role is critical in influencing students' adoption of this tool and beyond that, the degree to which students would use this tool; b) content relevance is more important than just participation because simply trying to promote higher participation may backfire; and c) teachers need to encourage students to post using their real names.

7.1 Teachers' Use of ClassCommons

The teacher's involvement with the tool seems to have an important influence on students' willingness to use a public backchannel. The ability of a teacher to participate in a backchannel is very much influenced by what other activities are ongoing (e.g., lecturing, group supervision). Thus it may be that modifications in class pedagogy are needed to enhance the effectiveness of public backchannels in classrooms.

The original idea of ClassCommons was to provide a public backchannel for students to raise questions and receive timely feedback from the teacher or other students. Although students can certainly learn some content from other students, they seem to be more eager to get responses from the teacher than from other students. This could be because teachers' responses are more authentic and teacher can provide more expert information. However, the way the teachers conduct their classes does not meet students' needs. In both classes, the teachers spent considerable time lecturing, such that they were not able to pay much attention to the things on the public display. Although these instructors had TAs available to monitor the public backchannel and answer questions, still the students wanted to get more acknowledgements from the teacher. It is unlikely that a teacher would be willing to make radical changes in how he or she conducts a class. However, it might be that even some very simple changes in practices could better integrate the backchannel with other class activities. For example one of the students suggested *"pause every 30 minutes to look at it"*. Other possibilities are to provide mechanisms for the students (or the TA) to gain the attention of the teacher, somewhat analogous to raising one's hand.

It is also interesting to think about the tradeoffs in teacher versus student attention. In a sense the public backchannel should be a "freeing" technology, enabling students to have their own interaction in parallel with whatever the teacher is doing. Although in this study we found an important effect of teacher attention, it would also be interesting to experiment with mechanisms for increasing students' responsiveness to each other. In fact the issue of anonymity may interact with student responsiveness – by using one's real name, one takes a public stand on a question or comment, and in time this may improve community and responsibility.

7.2 Content Quality

Content relevance was seen to be more important than simple participation. In these two classes, the teachers set different policies regarding how the students were expected to use ClassCommons. The instructor of PM did not allow students to post irrelevant contents while the instructor of HCI did not set such policy and any contents were welcome. This led to huge difference in the participation rate. A lot more messages were posted in HCI and much more percentage of the students posted in HCI than PM. However, the regression analyses suggested that content relevance played an important role in predicting use of ClassCommons and indirectly influencing sense of community in classrooms. If the public backchannel is solely left for students to post anything, it may backfire because "*this can get annoying*".

8. CONCLUSIONS

The 15 week field study provided us an opportunity to investigate the long term impact of public backchannel tools on students' sense of community in classrooms. It is encouraging that 90% of students were interested in using it in future classes. Based on the survey data, we modeled the ClassCommons usage pattern and found that content quality and students' interests were important factors that influence students' use of ClassCommons. Further, the use of ClassCommons is positively related to students' sense of community. The content analysis revealed how students have used the tool during the semester and the qualitative interview and students' answers to the open-ended questions enriched our understandings about the benefits and drawback of using public backchannel in classrooms.

9. ACKNOWLEDGMENTS

The authors would like to thank the teachers John Hill and Shaoke Zhang, and the students for their participation in this study.

10. REFERENCES

[1] Vygotsky, L. S. *Mind in society: The development of higher psychological processes*. Harvard University Press, Cambridge, MA, 1978.

[2] Dewey, J. *How we think*. D.C. Heath & Co, New York, 1910.

[3] Boyle, J. T. Using classroom communication systems to support interaction and discussion in large class settings. *Association for Learning Technology Journal*, 11, 3(2003), 43-57.

[4] Yngve, V. On getting a word in edgewise. In Proceedings of the Sixth Regional Meeting of the Chicago Linguistic Society (Chicago, 1970).

[5] Krauss, R. M. The role of audible and visible back-channel responses in interpersonal communication. *Journal of personality and social psychology*, 35, 7 (1977), 523-529.

[6] Bergstrom, T., Harris, A. and Karahalios, K. Encouraging initiative in the classroom with anonymous feedback. In *Proceedings of the Proceedings of the 13th IFIP TC 13 international conference on Human-computer interaction* - Volume Part I (Lisbon, Portugal, 2011). Springer-Verlag.

[7] Yardi, S. The role of the backchannel in collaborative learning environments. In *Proc. of 7th International Conference of Learning Sciences*, 2006.

[8] Harry, D., Green, J. and Donath, J. backchan.nl: integrating backchannels in physical space. In *Proc. of CHI 2009*, ACM.

[9] Dufresne, R., Gerace, W., Leonard, W., Mestre, J. and Wenk, L. Classtalk: A classroom communication system for active learning. *Journal of Computing in Higher Education*, 7, 2(1996), 3-47.

[10] Robertson, L. J. Twelve tips for using a computerised interactive audience response system. *Medical Teacher*, 22, 3(2000), 237-239.

[11] Fies, C. and Marshall, J. Classroom Response Systems: A Review of the Literature. *Journal of Science Education and Technology*, 15, 1(2006), 101-109.

[12] Ratto, M., Shapiro, R. B., Truong, T. M. and Griswold, W. The ActiveClass Project: Experiments in encouraging classroom participation. In *Proceedings of the CSCL (2003)*. Kluwer Academic Publishers.

[13] Anderson, R., Anderson, R., VanDeGrift, T., Wolfman, S. Y. and Yasuhara, K. Promoting Interaction in Large Classes with Computer-Mediated Feedback. In *Proceedings of the CSCL (2003)*. Kluwer Academic Publishers.

[14] Linnell, N., et al. Supporting classroom discussion with technology: A case study in environmental science. in *Frontiers In Education Conference - Global Engineering: Knowledge Without Borders, Opportunities Without Passports*, 2007. FIE '07. 37th Annual. 2007.

[15] EDUCAUSE 7 Things You Should Know About Live Question Tool. *EDUCAUSE* ,2011.

[16] Du, H., Rosson, M. B., Carroll, J. M. and Ganoe, C. I felt like a contributing member of the class: increasing class participation with Classcommons. *In Proceedings of the ACM 2009 international conference on supporting group work*. GROUP '09. ACM, 233-242.

[17] Du, H., Jiang, H., Rosson, M. B. and Carroll, J. M. Increasing Students In-Class Engagement through Public Commenting: An Exploratory Study. *In Proceedings of the 2010 10th IEEE International Conference on Advanced Learning Technologies* (2010). ICALT '2010, IEEE Computer Society, 373-377.

[18] Sanders, C. E., Basham, M. E. and Ansburg, P. I. Building a Sense of Community in Undergraduate Psychology Departments. *Observer*, 19, 5 (2006).

[19] Bendig, A. W. The Pittsburgh scales of social extroversion, introversion and emotionality. *The Journal of Psychology*, 53(1962), 199-209.

[20] Wrench, J. S., Richmond, V. P. and Gorham, J. *Communication, Affect, and Learning in the Classroom*. Tapestry Press, Acton, MA, 2001.

[21] Rovai, A. P. Development of an instrument to measure classroom community. *The Internet and Higher Education*, 5, 3(2002), 197-211.

[22] Peterson, N. A., Speer, P. W. and McMillan, D. W. Validation of A brief sense of community scale: Confirmation of the principal theory of sense of community. *Journal of Community Psychology*, 36, 1(2008), 61-73.

[23] Nunnally, J. C. *Psychometric Theory*. McGraw-Hill, New York, 1978.

[24] Bandura, A. Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, 84, 2(1977), 191-215.

[25] Bandura, A. Self-efficacy: *The exercise of control.* W.H. Freeman and Company, NY, 1977.

[26] Goddard, R. D., Hoy, W. K. and Hoy, A. W. Collective Efficacy Beliefs:Theoretical Developments, Empirical Evidence, and Future Directions. *Educational Researcher*, 33(2004), 3-13.

[27] Pedhazur, E. J. *Multiple Regression in Behavioral Research.* Harcourt Brace College Publishers, New York, 1997.