When Less is More: How Short-message Feeds in Social Media Platforms Affect Collaborative Learning

Completed Research Paper

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Abstract

Social media platforms bear the promise of enhancing interactions in collaborative learning. Yet, relatively little is known about how short-message feeds, a key feature in many social media platforms, affect collaborative learning. We report the results of a field experiment in which we manipulated the social media platform that 53 teams of four students used for a collaborative learning task over three weeks. We find that students provided with short-message feeds achieved significantly better learning outcomes than students without. While learner engagement was similar in both conditions, learner communication was more focused on the task in the condition with short-message feeds. The short-message feed led learners to curtail social communication and uncertainty statements, which mediated the effect of the short-message feeds on learning outcomes. Our study provides new insights into the effect of short-message feeds on collaborative learning and communication.

Keywords: Social media, learning, collaborative learning, microblogging, feed, computer-supported collaborative learning

Introduction

Many higher education institutions are placing importance on collaborative learning, i.e., on educational practices in which interactions among learners play a key role (Dillenbourg et al. 2009). Collaborative learning bears the promise of enhancing learner engagement and of allowing learners to capitalize on each other's knowledge (Kirschner et al. 2009; Wenger 1999; Zhao and Kuh 2004). Given the central role of interactions, the computer-supported collaborative learning (CSCL) community shows strong interest in understanding how information technology (IT) can support learner interaction in collaborative learning teams. A relatively recent class of IT that is rapidly diffusing in organizational and private life and that bears

the promise of enhancing learner interaction in collaborative learning are social media platforms (SMPs) such as Twitter and Facebook. SMPs are IT designed to facilitate collaboration, community building, participation, sharing, and awareness (Krancher et al. 2018; Leonardi 2015; Tess 2013; Treem and Leonardi 2012)—processes that are highly relevant for collaborative learning teams (Buder 2011; Kreijns et al. 2003). One of the key features of SMPs are short-message feeds to which learners can post short messages and which summarize team communication at one place. In this paper, we aim to advance knowledge about how the short-message feeds feature of SMPs affects collaborative learning in teams.

Although the existing literature on SMP use for collaborative learning is at a relatively early stage (Hew and Cheung 2013, p. 47), it provides useful perspectives on this question. A key finding is that SMPs can help increase learner engagement and improve learning outcomes (Gao et al. 2012). For instance, in one field experiment, students were assigned to two conditions, one in which students used the SMP Ning and one in which they used Ning and Twitter (Junco et al. 2011). Students in the Twitter condition reported higher degrees of engagement and obtained better learning outcomes than students in the Ning-only condition. Other studies, too, reported higher student engagement when popular SMPs such as Facebook were integrated into courses (Heiberger and Harper 2008; McCarthy 2010; Schroeder and Greenbowe 2009).

While these findings are insightful, important gaps remain. First, the design of the studies makes it difficult to attribute increased learner engagement to particular features of the SMP, such as short-message feeds. It may be that learners in the Twitter or Facebook conditions were more engaged because they had positive attitudes towards Twitter or Facebook, rather than because particular features of the SMP triggered higher engagement. Yet, without insights into the effects of particular features, it is difficult to provide learning environment designers with guidance on the effective design of SMPs. To provide such guidance, it is important to open the black box of SMPs and understand the effects of particular features. One such key feature are short-message feeds. Second, an important property of short-message feeds is that they impose a maximum length on feed posts, resulting in relatively concise messages. While short messages may have the positive effect of more frequent communication (Junco et al. 2011), they may also lead learners to curtail potentially important elements, such as social communication and cues about knowledge levels. We know little about the negative or positive effects of such curtailed communication (Tang and Hew 2017). Third, although the interest in CSCL research often lies on learning in team settings, existing research on the impact of SMPs tends to focus on course or program settings, rather than on team settings (Tess 2013).

Building on existing research on SMPs and CSCL, we argue that the short-message feed feature of SMPs can affect collaborative learning through two mechanisms. First, the short-message feed may help *engage learners* by increasing communication awareness (Krancher et al. 2018; Majchrzak et al. 2013) and by thus spurring content-related communication, which may lead to better learning outcomes. Second, short-message feeds may help *focus learners on the task*, encouraging learners to curtail social and uncertainty statements. This may have two opposite effects on learning outcomes. While reduced social and uncertainty statements may hamper team building (Kreijns et al. 2003), lead to more superficial levels of elaboration (Sangin et al. 2011), and, hence, result in weaker learning outcomes, reduced social and uncertainty statements may, alternatively, help reduce cognitive load and prevent satisficing norms, thus leading to better learning outcomes.

We tested these ideas through a field experiment, in which 53 teams of 4 students worked on a collaborative task over a period of three weeks. We randomly assigned these teams to two otherwise identical SMPs that differed only in the availability of short-message feeds. The results show significantly better learning outcomes in the short-message feeds condition. Mediation analyses suggest that reduced uncertainty statements received from team members and reduced social communication sent by learners mediated the effect. Hence, it appears that learners in the feed condition achieved better learning outcomes because they were more focused on the task. Our key contribution lies in providing new insights into the effect of short-message feeds on collaborative learning and communication.

Hypotheses Development

Drawing on the literatures on SMPs and CSCL, we argue that short-message feeds in SMPs affect collaborative learning by helping to engage learners and to focus learners on the task. Figure 1 shows our hypotheses. The hypotheses H1 and H2a/b relate to increased learner engagement and its effect on learning

outcomes. H3 through H8a/b relate to increased task focus and its (rival) effects on learning outcomes. H9 and H10 are rival hypotheses describing the overall effect of the feed feature on learning outcomes.

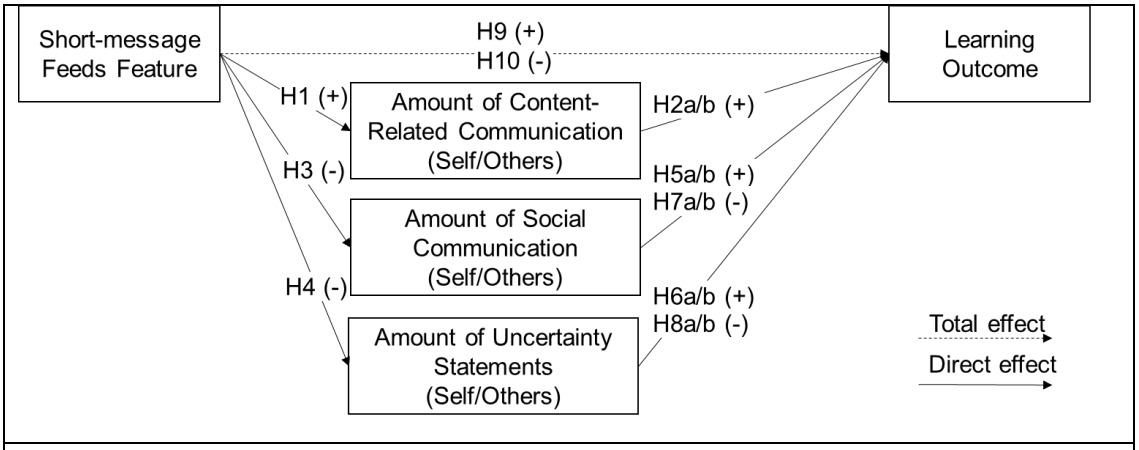

Figure 1. Research Model

Engaging Learners

A shared theme in research on SMP use in collaborative learning is that SMPs help raise learner engagement (Gao et al. 2012; Junco et al. 2011; McCarthy 2010). Although learner engagement is a broad construct (Junco et al. 2011; Kuh 2009), a key facet of learner engagement is content-related communication, i.e., messages related to the substance of the collaborative learning task (Dehler et al. 2009, p. 119). Existing studies focus on the mechanisms through which SMPs in general, rather than their feed features, help raise learner engagement. These studies argue that SMPs help enhance learner engagement because they invite contributions by learners that otherwise would hesitate to contribute, because SMPs enable contributions at any time, and because SMPs help sustain high levels of interaction over time (Gao et al. 2012). While the first two mechanisms may be true for SMPs irrespective of whether they include a feed, the feed feature may play a key role for sustaining high levels of interaction over time. Feeds may help sustain high levels of interaction because feeds increase communication awareness by tying together communication from different channels at one place (Krancher et al. 2018). This makes it easier for team members to respond to ongoing content-related conversations in a steady and timely manner, resulting in higher amounts of content-related communication. Short-message feeds (as opposed to feeds without message size restrictions) may be particularly well suited for maintaining such intense chains of interaction because short messages are easy to process, making it easier to respond quickly. We therefore anticipate:

H1: Learners that have short-message feeds available send higher amounts of content-related communication than learners that do not have short-message feeds available.

Higher student engagement in terms of higher amounts of content-related communication may affect learning outcomes in two ways. First, when learners make content-related statements, they recapitulate and cognitively elaborate information from the task domain, helping learners to build and refine cognitive schemas in the task domain. Schema acquisition and refinement by elaborating information from the task domain are key learning processes (Chi et al. 1989; Reigeluth 1999). This is in line with the strong general support for an effect of student engagement on learning outcomes (Kuh 2009). Second, not only the learner's own content-related statements but also the team members' content-related statements bear learning opportunities. One of the key ideas behind collaborative learning is that learners learn from each other's knowledge when they interact (Dillenbourg et al. 2009; Wenger 1999; Zhao and Kuh 2004). For instance, team members share their knowledge, raise critical questions that spur elaboration, or help each other during problem solving (Kirschner et al. 2009). We therefore expect:

H2a/b: Higher amounts of content-related communication sent by learners (a)/ team members (b) are associated with better learning outcomes.

Focusing Learners on the Task

The short-message feed feature of SMPs may help not only to engage learners but also to focus learners on the task. Short-message feeds, characteristic for microblogging SMPs such as Twitter, impose length restrictions on posts and thereby lead users to communicate through very brief messages (Tess 2013). Indeed, one study on Twitter use found that 69% of the learners spent on average a maximum of two minutes for creating a post (Borau et al. 2009), highlighting the short nature of messages on Twitter. We argue that message size restrictions may lead learners to curtail messages to the content-related essence, reducing other elements of their communication. Specifically, learners may reduce two dimensions of their communication that are emphasized by CSCL scholars: social communication (Kreijns et al. 2003) and uncertainty statements (Sangin et al. 2011). Social (or interpersonal) communication refers to the relations among team members and may include praise, thank, dissatisfaction, and conversations not related to the collaborative task in its narrow sense (Kreijns et al. 2003; Weisband 2002). Uncertainty statements are statements wherein learners express their lack of confidence about their claims or their lack of knowledge in a particular area, such as in hedging statements like "I don't remember well but" or "It seems to me that" (Brennan and Ohaeri 1999; Sangin et al. 2011). Although computer-supported communication is generally held to be associated with reduced use of social communication (Kreijns et al. 2003) and uncertainty statements (Brennan and Ohaeri 1999), the short-message feed feature with its message length restrictions may lead learners to further reduce these elements in their communication. We expect:

H3: Learners that have short-message feeds available send lower amounts of social communication than learners that do not have short-message feeds available.

H4: Learners that have short-message feeds available send lower amounts of uncertainty statements than learners that do not have short-message feeds available.

While it appears likely that short-message feeds curtail social communication and uncertainty statements, the impact of such curtailed communication on learning is more controversial. We next provide the arguments for two rival perspectives, one that emphasizes the benefits from social and uncertainty statements in CSCL and one that emphasized the benefits from keeping communication focused on the task.

A key concern in research on CSCL is that computer-mediated communication depersonalizes communication, which hampers team development and, ultimately, learning outcomes. For instance, Kreijns et al. (2003) stress "a social (psychological) dimension to the social interaction in collaborative learning … [which] relates to processes that have to do with getting to know each other, committing to social relationships, developing trust and belonging, and building a sense of on-line community … processes [that] are not related to the task in the strict sense." (p. 342) In line with these ideas, there is strong evidence of the importance of social (or interpersonal) processes both for learning (Edmondson 1999; Van den Bossche et al. 2006) and for team performance (Bradley et al. 2003; Mathieu and Schulze 2006). According to this perspective, social communication can help improve learning outcomes because social communication is critical for team development, which may lead to improved social interaction (e.g. helping behaviour) and, as a consequence, to better learning outcomes (Kreijns et al. 2003). This perspective, hence, problematizes the reduced social communication that may result from the use of short-message feeds. We hypothesize:

H5a/b: Higher amounts of social communication sent by learners (a)/ team members (b) are associated with better learning outcomes.

In a similar vein, CSCL research emphasizes the benefits from uncertainty statements (Brennan and Ohaeri 1999; Sangin et al. 2011). Uncertainty statements sensitize learners for the fragility of their knowledge or what Sangin et al. (2011) term *epistemic uncertainty*. When learners are sensitized for the fragility of their own and their team members' knowledge, they are more inclined to question their own and their team members' ideas, leading to more elaborated communication, deeper processing, and ultimately improved learning outcomes. For instance, Sangin et al. (2011) provided some teams with a knowledge-awareness tool that informed learners about their own and their peers' knowledge. This led to higher amounts of uncertainty statements, more elaborated communication, and better learning outcomes. According to this perspective, reducing uncertainty statements by inviting learners to curtail their communication in a short-message feed should lead to poorer learning outcomes:

H6a/b: Higher amounts of uncertainty statements sent by learners (a)/ team members (b) are associated with better learning outcomes.

A rival perspective emphasizes the benefits from keeping learners more focused on the task when social communication and uncertainty messages are reduced. Social communication and uncertainty messages may hamper learning in two major ways. First, social communication and uncertainty messages impose additional cognitive load on learners because learners need cognitive resources to write and to understand these messages. According to cognitive load theory, such extraneous cognitive load (i.e., cognitive load that does not result from the inherent complexity of the learning task) hampers learning in particular for complex learning tasks because it deprives learners of the resources that they would need to process information from the domain of the learning task (Kirschner et al. 2009; Sweller et al. 1998). Cognitive overload may result in poorer learning outcomes (Krancher and Dibbern 2012; Sweller et al. 1998). Second, social communication and uncertainty messages may promote what we call satisficing norms, i.e., the shared belief that knowledge gaps and imperfect work products are acceptable. To the extent that learners and their team members send uncertainty statements, they may not only sensitize each other for the fragility of knowledge (which may be beneficial for learning, see H6a/b); they are also creating and reinforcing the norm that knowledge gaps are normal, reducing thus the aspiration levels in the group. For instance, when a learner hears from team members that they struggle with the subject matter, the learner may infer that these team members may be satisfied even with a mediocre grade on the task, which may reduce the pressure on the learner to devote high effort to the task. In a similar vein, when learners or their team members are sending social communication, they may send the signal that their work products are at a sufficient level, allowing the team to shift the communication to topics unrelated to the learning task and leading, hence to lower aspiration levels. We hypothesize:

H7a/b: Higher amounts of social communication sent by learners (a)/ team members (b) are associated with weaker learning outcomes.

H8a/b: Higher amounts of uncertainty statements sent by learners (a)/ team members (b) are associated with weaker learning outcomes.

The arguments as laid out in H1 through H8a/b suggest that short-message feeds may be either beneficial or harmful for learning, depending on whether the positive or the negative effects of keeping learners more focused on the task dominate and depending on the extent to which short-message feeds help engage learners. We therefore posit two rival hypotheses about the total effect of short-message feeds on learning outcomes:

H9: Learners that have short-message feeds available achieve better learning outcomes.

H10: Learners that have short-message feeds available achieve weaker learning outcomes.

Methods

Participants and Tasks

We tested our hypotheses through a field experiment in an undergraduate course on business process management at a Swiss university. The collaborative learning task was a comprehensive business process improvement case, where teams of 4 students were asked to map, analyze, and improve the credit approval processes at a bank. The teams had three weeks to work on the task. Students were randomly assigned to 54 teams of 4 students. 36% of the students were female. The average age was 22. Most students were in their fifth semester since their start of studies.

Treatment

We randomly assigned 27 teams to the control condition and 27 to the treatment condition. In the control condition, teams were provided with a collaboration platform that offered the following capabilities: (1) communication (team forums, direct messages, document annotations, profile updates; all allowing messages of unlimited length); (2) friend relationships (adding other people as friends); (3) artifact editor (integrated Google Docs word processor, spreadsheets, and diagrams). These capabilities are common to SMPs (Leonardi et al. 2013). In the treatment condition, teams were provided with a collaboration platform that offered all capabilities of the control condition and, in addition, a team feed and a friend feed. The content of the team feed was visible to team members only and the content of the friend feed was visible to friends only. The learners were able to make or reply to posts to these feeds. Like in popular SMPs such as

Twitter, feed posts (but not responses to feed posts) were limited to a maximum length, which was set to 200 characters. The feed showed not only the learners' feed posts and responses but also summaries of actions that the learners performed outside the feed, such as forum posts. Thus the short-message feed differed from other communication features such as the forum in that (1) message size was constrained and (2) the feed also summarized actions performed elsewhere (e.g. in team forums). We made these design decisions to make the feeds consistent with the way in which feeds in many SMPs, such as Facebook, operate. We used two highly similar platforms that differed only in the availability of feeds to facilitate attributing differences to this particular feature.

Procedures

At the outset, the participants had one week to familiarize themselves with the platform. During that period, the participants responded to a prequestionnaire, watched a 10-minute video that introduced them to the platform, and then obtained personal credentials to access the platform. Although the participants were informed that they were allowed to meet physically, they were encouraged to use the platform as much as possible, and they were able to access the case material and the shared artifacts through the platform only. Moreover, while the platform did not allow sending messages to students assigned to a different platform, the participants were informed that they were allowed to exchange information with members from other teams assigned to the same platform. This was supposed to make our study setting more realistic, given that SMPs typically allow communicating not only within but also beyond teams (Leonardi 2015).

After the one-week familiarization period, the participants had three weeks to complete the task. In one team from the control condition, students complained about two team members not participating in the group work. We therefore removed this team from our sample. After the three weeks, the platform was frozen and the participants were invited to respond to a postquestionnaire. The team deliverables were subsequently graded by an assessor, who was neither a member of the research team nor the platform administrator. The grade on the task made up 11% of the overall grade on the course. Students were able to choose between two dates for the course exam. The first date was two weeks and the second date two months after the hand-in of the collaborative task. Both exams included questions related to the learning goals of the collaborative task (particular techniques for process mapping, analysis, and improvement) as well as questions unrelated to these learning goals. The questions included multiple-choice questions and a process mapping problem that required learners to create a valid business process model. 191 unique students participated in the exams. We recorded both the score earned on the questions related to the learning goals and the score earned on the unrelated questions.

Measures

Our measurement approach combined data from multiple sources: data extracted from the collaboration platform, exam scores, pre- and post-surveys, and grade point average (GPA) scores obtained from the university's internal records. The upper part of Table 1 shows our measures for dependent, independent, and mediating variables. Our dependent variable, learning outcome, was measured through the score that students obtained in their first exam attempt on those questions that were related to the learning goals of the collaborative task. The measurement approach of assessing learning outcomes through a test addresses Kirschner et al.'s (2009) criticism that CSCL research often measures learning indirectly by measuring task performance during the learning phase, instead of the more valid approach of measuring "actual learning outcomes in a test phase specifically designed for testing learning and/or transfer" (p. 33). Since scores stemmed from two different exam attempts, we standardized the scores for each exam attempt before we pooled them. Our independent variable, the availability of the short-message feeds feature was a dichotomous variable reflecting the treatment to which the student was randomly assigned. Our mediator variables were the amount of communication of three different types (content-related, social, uncertainty). To obtain information on the amount of different types of communication, we extracted all team-internal messages (i.e., direct messages, forum posts, feed posts and responses, document annotations) from the platform and performed a content analysis (Krippendorff 2012). The unit of coding was the message. Each message was coded by two coders according to whether the message included content-related, social, and/or uncertainty messages. A message could be coded to relate to none, one, or more of these categories. Table 1 provides more specific coding guidelines. The coders were initially trained with training data before they began coding. They were blind to the hypotheses.

Table 1. Measures	
Dependent, independent, and mediating variables	
Learning outcome	Score obtained in the exam on questions related to the learning goals of the collaborative tasks. If a learner enrolled to both exam attempts, we used the score from the first attempt.
Short-message feeds feature	1 if the learner was assigned to the treatment condition (short-message feeds available); 0 otherwise
Amount of content-related messages (self/others)	The number of content-related messages that the learner (self)/ the learner's team members excluding the learner (others) sent over the platform (transformation: logarithm). Content-related messages are statements or questions that refer to the substance of the task, including messages referring to the approach for solving the task and feedback on team deliverables, but not including the discussion of coordination strategies or of formalities (e.g. font size).
Amount of social messages (self/others)	The number of social messages that the learner (self)/ the learner's team members excluding the learner (others) sent over the platform (transformation: logarithm). Social messages are messages referring to the relations among team members, including praise, thanks, dissatisfaction, and conversations not related to the collaborative task.
Amount of uncertainty statements (self/others)	The number of uncertainty statements that the learner (self)/ the learner's team members excluding the learner (others) sent over the platform (transformation: logarithm). Uncertainty statements are statements wherein the sender expresses lack of knowledge or lack of confidence about the correctness of own statements.
Control variables	
Gender	1 if the learner was female according to the prequestionnaire; 0 otherwise
Age	The learner's age according to the prequestionnaire
Semester	The learner's semester according to the prequestionnaire
Business major	1 if the learner was enrolled to a major in business administration; 0 otherwise
First exam attempt	1 if the learning outcome score is from the first exam attempt; 0 if it is from the second exam attempt
Grade point average (self)	The learner's grade point average (GPA) during the first-year courses of the study program
Grade point average (others)	The team members' average GPA during the first-year courses of the study program
Unrelated exam score (self)	The score that the learner obtained on questions that were not related to the learning goals of the collaborative task
Unrelated exam score (others)	The average score that team members obtained on questions that were not related to the learning goals of the collaborative task
Free rider (self)	1 if the learner was coded to be a free rider, otherwise 0. A learner was coded a free rider if at least of four conditions were met: (1) the communication records indicate that the learner did not make any contributions beyond final editing of the deliverables; (2) the learner's team members expressed their dissatisfaction with the learner's efforts; (3) the learner encouraged the team to spend little effort on the collaborative task; (4) the learner communicated only after the first week and after being summoned by a team member.
Free rider (others)	1 if at least one of the team members was coded to be a free rider; 0 otherwise
Offline Communication	The team's amount of communication outside the collaboration platform as indicated by the average of three items from postquestionnaire adapted from (Ma and Agarwal 2007) (Cronbach's alpha: 0.94)

Although we experimentally manipulated our independent variable, which reduces concerns related to endogeneity, we included a number of control variables to ensure the validity of our mediation analysis. Even in experimental research, mediation analyses are subject to endogeneity threats unless appropriate control variables are used (Antonakis et al. 2014). The lower part of Table 1 shows control variables. We controlled for the demographic factors gender, age, semester, and the learner's study major. Since the measures for our dependent variable, learning outcome, stemmed from two different exams to which the

students had the choice to register, we also controlled for whether the student enrolled to the first exam. Moreover, we included the learner's first-year grade point average (GPA) and the exam score on questions unrelated to the collaborative task to help control for individual-level differences in abilities and motivation. We also included the team members' GPA and unrelated exam scores to control for the team members' differences in abilities and motivation given that collaborative learning involves also learning from others and that individual-level differences in team members may, hence, affect learning. To further capture differences in motivation, we controlled for whether the learner and the team members were free riders, using a relatively mild coding rule (see Table 1). Furthermore, we controlled for the team's offline communication (i.e., the amount of communication outside the tool) based on responses to the post-questionnaire. We standardized all variables except for dichotomous variables to ease interpretation.

Data Analysis

We examined random assignment and potential self-selection bias due to the fact that only 191 out of 212 students took the exam. To this end, we used data on 11 individual-level factors from the pre-questionnaire. We examined differences in these factors between platform conditions, both among those that participated in the exam (our final sample) and those that did not. We did not find any significant differences at the .05 level, supporting thus random assignment and providing no evidence of self-selection bias.

We tested the total effect of our treatment (availability of short-message feeds, H9 and H10) on learning outcomes both using t tests and using a linear regression model with control variables. We examined that the assumptions of linear regression were met. Residual plots followed normal distributions. VIF values were equal to or lower than 2.7. Moreover, since students were nested within teams, we examined whether the observations of our dependent variable were independent. To this end, we specified a mixed-effects model with a random intercept at the team level. The variance of this random intercept indicates the extent of correlation within teams. The model estimated a variance of 0 for the random intercept, indicating thus that the assumption of interdependence at the individual level is appropriate.

To test mediation as hypothesized in H1 through H8, we proceeded as follows. First, we tested the direct effect of the availability feeds on the amounts of communication of the three types using the full sample of learners participating in the study (rather than only those having enrolled to the exam). Since the mediators were count data, we used Mann-Whitney tests. Second, we tested the direct effects of the mediators on our dependent variable using a regression model that included the treatment and control variables. Third, we used Hayes bootstrapping methods to obtain confidence intervals for the indirect effects of each mediator.

Results

Platform Usage

Before reporting the results of hypothesis testing, we present data about the usage of the platform. Table 2 shows the average amount of messages per learner and average length of these messages, grouped by communication feature. Overall, students in the condition without feeds sent, on average, slightly fewer messages (9.2) than students in the condition with feeds (10.4) (difference not significant, $p=.428$). The communication features through which the students sent these messages differed substantially between conditions. Students in the condition without feeds used mostly forum posts for communication, with 7.4 forum posts per student. Conversely, students in the feeds condition made only 2.2 forum posts, while they made ample use of team feed posts (3.3) and team feed responses (3.1)—features that were not available in the platform without feeds. Although the platform offered both team feeds and friend feeds, friend feeds played a marginal role (0.04 friend feed messages per learner). On average, messages sent on the platform with feeds were significantly shorter (175 characters) than messages sent on the platform without feeds (256 characters) (see the figures in parentheses in Table 2, $p<.001$). In particular the messages sent through team feed posts (126 characters) and team feed responses (129 characters) – features that were available only on the platform with feeds – were shorter than forum messages (231 characters on the platform with feeds and 230 on the platform without feeds). Akin to a manipulation check, data on platform usage, hence, shows that our manipulation affected the ways how the participants communicated over the platform. They sent the majority of messages over feeds, which led to significantly shorter messages. Our records also show that the teams spent substantial efforts on the collaborative task. Teams sent, on average, 39 messages and spent 26 hours editing artifacts (not tabulated), indicating that the teams used the platform extensively.

Table 2. Platform Usage: Number of Messages per Learner			
	No feeds condition	Feeds condition	Length significantly different (Mann-Whitney test)
Forum posts: Number (average length in characters)	7.4 (231)	2.2 (230)	No (p=.451)
Team messages: Number (average length)	1.3 (462)	1.4 (317)	No (p=.127)
Friend messages: Number (average length)	0.1 (192)	0.1 (280)	No (p=.384)
Team feed posts: Number (average length)	-	3.3 (126)	-
Team feed responses: Number (average length)	-	3.1 (129)	-
Friend feed posts: Number (average length)	-	0.04 (102)	-
Document annotations: Number (average length)	0.4 (83)	0.2 (106)	Marginally different (p=.072)
All messages: Number (average length)	9.2 (256)	10.4 (175)	Yes (p<.001)

Hypotheses Testing

Table 3 compares learning outcomes and communication between the two conditions. Table 4 shows bivariate correlations among all variables. Table 5 shows the regression results.

Table 3. Learning Outcomes and Communication per Platform: Means and Standard Errors				
	N	No feeds condition	Feeds condition	Difference significant
Learning outcome (standardized)	191	-.153 (.98)	.155 (1.00)	Yes (p = .033, t test)
Amount of content-related communication (Self)	212	2.43 (2.91)	2.42 (3.43)	No (p = .361, Mann-Whitney test)
Amount of social communication (Self)	212	2.20 (2.70)	1.61 (2.34)	Yes (p = .013, Mann-Whitney test)
Amount of uncertainty statements (Self)	212	.58 (.87)	.43 (.92)	Yes (p = .037, Mann Witney test)

We begin by describing the total effect of our treatment on learning outcomes as hypothesized in H9 and H10. The results show a significant positive total effect of the availability of short-message feeds on learning outcomes. As Table 3 shows, learners that had feeds available achieved standardized learning outcome scores of .155, whereas learners without feeds (i.e., learners in the control condition) achieved -.153, corresponding to an effect size of .31. The difference was statistically significant (p = .033, t test). Mirroring these results, the availability of feeds is a significant predictor of learning outcomes in our regression model 1 (β = .31, p = .033, see Table 5). The effect of the feeds condition remains significant when control variables are added in model 2 (β = .30, p = .025), indicating that the significant effect of the treatment is unlikely to be due to the assignment of particular students to particular experimental conditions. Taken together, these findings support the positive effect of the availability of short-message feeds on learning outcomes hypothesized in H9, and they lead us to reject H10.

The analysis that follows gives insights into the mediating factors behind this positive effect. In H1, H3, and H4, we hypothesized that learners would send higher amounts of content-related communication (H1), lower amounts of social communication (H3), and lower amounts of uncertainty statements (H4) when they had short-message feeds available. As Table 3 shows, learners sent about the same amount of content-related communication with and without feeds (2.43 vs. 2.42, p = .361, Mann-Whitney test), providing no support for the idea that the feed would help engage learners by making them send higher amounts of content-related communication. Thus H1 is not supported. Conversely, the amounts of social communication and of uncertainty statements differed between platform conditions. Learners sent significantly lower amounts of social communication when feeds were available (1.61 vs. 2.20, p = .013, Mann Whitney test), supporting H3. They also sent significantly fewer uncertainty statements (.43 vs. .58, p = .037, Mann Whitney test), supporting H4.

Table 4. Bi-variate Correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
(1) Learning	1																			
(2) Feeds	.15	1																		
(3) Gender	-.08	-.07	1																	
(4) Age	-.16	-.06	-.02	1																
(5) Semester	-.05	-.06	-.09	.46	1															
(6) Business Major	.08	.12	-.08	.01	-.11	1														
(7) First Exam	-.04	.02	.02	.02	.00	-.14	1													
(8) GPA (self)	.38	-.04	-.03	-.10	-.19	-.01	-.10	1												
(9) GPA (others)	.05	-.07	-.04	.01	.07	-.09	-.06	-.02	1											
(10) Exam unrel. (self)	.23	.07	-.05	-.03	-.01	.04	.06	.15	.12	1										
(11) Exam unr. (others)	.05	.11	-.07	-.03	-.07	.00	-.04	.12	.25	.11	1									
(12) Free rider (self)	-.13	-.04	-.10	-.02	.07	-.01	-.11	-.06	.16	-.05	.09	1								
(13) Free rider (others)	.13	-.03	.05	-.04	.03	.05	-.07	.16	.09	.09	.04	.02	1							
(14) Offline	-.11	.03	.14	-.03	-.01	.04	.04	-.07	-.11	-.02	-.03	-.03	-.03	1						
(15) Content (self)	.13	-.05	.13	.01	-.15	.08	.11	.19	.06	.17	.13	-.15	.10	-.25	1					
(16) Content (others)	-.15	-.10	.12	.05	.02	.03	.00	.04	.19	.06	.16	.02	-.04	-.29	.60	1				
(17) Social (self)	-.10	-.16	.26	.22	.08	.01	.07	.09	.06	.12	.12	-.01	.10	-.05	.41	.30	1			
(18) Social (others)	-.11	-.22	.14	.19	.09	-.03	.01	.04	.09	.08	.15	.14	.10	-.02	.32	.46	.52	1		
(19) Uncertainty (self)	.09	-.10	.00	.00	-.06	.00	.05	.17	.11	.15	.02	-.11	.12	-.10	.51	.27	.23	.15	1	
(20) Uncert. (others)	-.18	-.21	.15	.02	.03	-.07	-.12	.12	.26	.00	.09	.04	.00	-.15	.32	.60	.17	.29	.16	1

(n = 191, correlations greater than or equal to .12 are significant at $p < .05$)

Table 5. Regression Results

	Model 1 (treatment only)	Model 2 (+ control variables)	Model 3 (+ mediators)
Intercept	-0.15 (0.10)	-0.30 (0.37)	-0.41 (0.35)
Short-message feed feature	**0.31* (0.14)**	**0.30* (0.13)**	0.20 (0.13)
Gender	-	-0.08 (0.14)	0.08 (0.14)
Age	-	**-0.17* (0.07)**	**-0.16* (0.07)**
Semester	-	0.11 (0.07)	**0.17* (0.07)**
Major in business	-	0.30 (0.26)	0.29 (0.25)
First exam attempt	-	-0.01 (0.15)	-0.08 (0.14)
Grade point average (self)	-	**0.35*** (0.07)**	**0.36*** (0.07)**
Grade point average (others)	-	0.06 (0.07)	**0.14* (0.07)**
Unrelated exam score (self)	-	**0.14* (0.07)**	**0.13* (0.07)**
Unrelated exam score (others)	-	-0.03 (0.07)	-0.01 (0.07)
Free rider (self)	-	**-0.49† (0.28)**	-0.38 (0.27)
Free rider (others)	-	0.16 (0.20)	0.03 (0.19)
Offline Communication	-	-0.08 (0.07)	-0.12 (0.07)
Content-related communication (self)	-	-	**0.29** (0.10)**
Content-related communication (others)	-	-	**-0.25* (0.10)**
Social communication (self)	-	-	**-0.18* (0.08)**
Social communication (others)	-	-	0.10 (0.10)
Uncertainty statements (self)	-	-	-0.02 (0.07)
Uncertainty statements (others)	-	-	**-0.20* (0.08)**
R^2	.02	.25	.36
Adjusted R^2	.02	.20	.29
F	**4.61***	**4.60*****	**4.99*****
F Change (df)	**4.61* (1, 189)**	**4.51*** (12, 177)**	**4.62*** (6, 171)**

***p <.001, **p <.01, *p <.05, †p <.10, n=191, all non-dichotomous variables standardized, standard errors in parentheses, significant number in bold

The regression results on model 3 (see Table 5) show how these potential mediating factors were related to learning outcomes. Adding the mediators to the model yields a substantial increase of variance explained (ΔR^2 = .11), highlighting the explanatory power of the mediators. The amount of social communication sent by the learner had a significant negative relationship to learning outcomes (β = -18, p = .022), supporting H7a and rejecting H5a. Hence, learners achieved better learning outcomes when they sent fewer social messages. In contrast, the amount of social communication sent by team members was not significantly related to the learner's learning outcomes (β = .08, p = .34), providing no support for H7b or H5b. The results on uncertainty statements showed the opposite picture. The number of uncertainty statements sent by learners was not related to learning outcomes (β = -.02, p = .83), providing no support for H6a or H8a. In contrast, the number of uncertainty statements received from team members was negatively related to the learner's learning outcomes (β = -.20, p = .018), supporting H8b and rejecting H6b. Thus, learners achieved better learning outcomes when their team members sent fewer uncertainty statements. Although the results on content-related communication are not relevant for the discussion of mediation effects due to lack of differences between platforms in the amount of content-related communication, we note that learning outcomes were positively predicted by the learner's content-related communication (β = .29, p =

.003, supporting H2a) and negatively by the team members' content-related communication (β = -.25, p = .012, rejecting H2b). The results on model 3 also show that the short-message feed feature is no longer significantly related to learning outcomes (β = .20, p = .13) once the potential mediators are included in the model.

The discussion thus far suggests two potential mediating factors that help explain the effect of the feeds condition on learning outcomes: the lower amount of social communication sent by learners and the lower amount of uncertainty statements received from team members. We ascertained the significance of these indirect effects by using Hayes' bootstrapping procedure in SPSS (Hayes 2017; Preacher and Hayes 2008). The results show a significant indirect effect of the availability of feeds on learning outcomes via the team members' uncertainty statements (indirect effect size = .065, p < .05) and a marginally significant indirect effect via the learner's social communication (indirect effect size = .054, p <.10).

In conclusion, our mediation analysis suggests the following interpretation. Learners in the feeds condition achieved better learning outcomes because they sent lower amounts of social communication and because they received lower amounts of uncertainty statements from their team members. It seems, hence, that the short-message feeds with their length restriction of 200 characters per feed post led to shorter messages (see also Table 2) and that the need to write shorter messages urged learners to reduce social communication and uncertainty statements. This kept the learners more focused on the substance of the task, which apparently yielded higher learning outcomes.

Table 6. Indirect Effects

Mediator	Indirect effect size	Mediation effect
Content-related communication (self)	-.037	Not supported
Content-related communication (others)	.049	Not supported
Social communication (self)	**.054**†	Weakly supported
Social communication (others)	-.033	Not supported
Uncertainty statements (self)	.003	Not supported
Uncertainty statements (others)	**.065***	Supported

***p <.001, **p <.01, *p <.05, †p <.10, n = 191, number of bootstrap samples: 20,000, significant number in bold

Table 7 and Table 8 shed light on the role of the short-message feed feature in bringing about reduced social communication and fewer uncertainty statements. The tables show the fractions of social messages (Table 7) and of uncertainty statements (Table 8) in messages sent through forum posts, team feed posts, and team feed responses, the three most extensively used communication channels. As Table 7 shows, the fraction of messages that contained social communication was lowest for team feed posts (which were limited to a length of 200 characters) (9%), somewhat higher for team feed responses (14%) and still higher for forum posts (23% and 20% on the platform without and with feeds). In a similar vein, Table 8 shows that the fraction of messages with uncertainty statements was lower for team feed posts (3%) and for team feed responses (3%) than for forum posts (6% on the platform with feeds and 5% on the platform without feeds). Hence, the students sent about similar fractions of social messages and uncertainty statements when they used the forum feature on both platforms, but fewer social messages and uncertainty statements when they used feed posts and feed responses, features available only on the platform with feeds. In sum, it seems that the use of the short-message feeds led to fewer social messages and uncertainty statements and that this helped focus learners on the substance of the task, which yielded higher learning outcomes.

Table 7. Fractions of Social Messages per Communication Feature

	Platform without Feeds	Platform with Feeds
Forum posts	23%	20%
Team feed posts	-	9%
Team feed responses	-	14%

Table 8. Fractions of Messages with Uncertainty Statements per Communication Feature		
	Platform without Feeds	Platform with Feeds
Forum posts	6%	5%
Team feed posts	-	3%
Team feed responses	-	3%

Alternative Explanations

To corroborate this interpretation, we examined a number of alternative explanations. First, one may argue that the short-message feed, with its length restrictions of 200 characters per feed post, encouraged learners to make more concise postings, which demanded greater cognitive elaboration and produced, hence, better learning outcomes. We therefore added the average length of messages sent by the learner as an additional variable to those present in model 3. The regression coefficient of that variable was insignificant ($p = .94$, results not tabulated) and the effects of mediating factors remained significant. Hence, is seems that it was the reduction of social communication and of uncertainty statements, rather than more concise communication per se that promoted learning. Second, one may argue that the use of the feed feature (instead of the forum) caused better learning outcomes through mechanisms not depicted in our model and that the correlations between social communication and learning outcomes and between uncertainty statements and learning outcomes are spurious. To examine this possibility, we added the (logarithmized) number of feed posts by group to model 3. The regression coefficient was insignificant ($p = .26$) and the effects of the mediating factors remained significant, indicating that learning outcomes improved not due to the use of feed posts per se but due to reduced social and uncertainty messages. Third, one may reason that seeing all communication summarized in the feed might incline learners to respond more frequently to content-related questions and that this more interactive communication explains learning outcomes. We therefore coded the number of answers that learners received on their questions. When we added the average number of answers per question as an additional predictor to model 3, we found an insignificant regression coefficient ($p = .12$) and the effects of the mediating factors remained significant. Fourth, as argued by Krancher et al. (2018), the feed may allow teams to benefit from a steadier stream of communication. Following research on the role of spacing in learning (Cepeda et al. 2008), a steadier stream of communication might lead to better learning. We therefore added the number of days on which a team sent content messages to model 3. We found an insignificant regression coefficient ($\beta = .00$, $p = .97$), and the effects of the mediating factors remained significant. Fifth, to explore whether familiarity of team members was an important omitted variable, we controlled for the number of friends in the team according to self-reported data from the pre-questionnaire. The coefficient was insignificant ($\beta = .00$, $p = .99$).

Discussion

This study was motivated by the lack of research that examines the effect of short-message feeds—a key feature of SMPs—on collaborative learning, despite the promises that the use of SMPs bears for supporting collaborative learning. Our field experiment shows that feeds can enhance learning outcomes and it gives insights into the mechanisms through which the use of feeds can translate into better learning outcomes.

Engaging Learners

Drawing on existing field studies of Twitter and Facebook use in collaborative learning settings (Junco et al. 2011; Schroeder and Greenbowe 2009), we expected that short-message feeds could help increase learner engagement, as indicated by higher amounts of content-related communication. As our results on H1 revealed, this expectation is not supported by our data. Learners in the feed condition sent about as much content-related communication as learners without feeds. Although the amount of content-related communication by learners was positively related to their learning outcomes (as hypothesized in H2a), the feed feature did not help promote content-related communication. We suggest two explanations for the discrepancy between our findings and findings of higher student engagement associated with SMP use reported in the literature. First, while existing research argues that SMPs raise engagement by allowing

contributions at any time and by encouraging contributions from students who would otherwise not contribute (Gao et al. 2012, p. 791), these effects are unlikely to be consequences of the feed feature. Most computer-supported collaboration systems (including the one in our control condition) will allow learners to make contributions at any time. Moreover, the reasons for why SMPs such as Facebook and Twitter encourage students to contribute could be related to the popularity of these platforms among students or to the informal image of these platforms rather than to particular features. Hence, while the opportunity to use tools liked by learners may spur engagement, it does not seem that the mere availability of a feed leads to more intensive interaction over the course of a collaborative task. Second, while existing research argues that SMPs help sustain a high level of interaction because they allow triggered attending (Gao et al. 2012, p. 791; Majchrzak et al. 2013), such dynamics may operate in large social units such as the students enrolled to a course or to a study program, but they may not unfold in the relatively small unit of collaborative learning teams, such as the teams of four used in our study. This suggests that effects found in SMP use in course or program settings, need not transfer to collaborative learning executed in team settings.

Focusing Learners on the Task

We further argued that, due to the length restrictions associated with feed posts, short-message feeds would help focus learners on the task, as indicated by fewer social messages and fewer uncertainty statements. In line with these expectations, our results on H3 and H4 show that the availability of the short-message feed feature can lead learners to send fewer social messages and uncertainty statements. Specifically, when learners sent messages through feed posts (where the length of messages was constrained to a maximum of 200), these messages included less frequently social elements or uncertainty statement than messages sent through other features such as forums. Hence, it appears that it is due the feed feature with its length restrictions that students send fewer social messages and uncertainty statements when feeds are available. While students sent fewer social messages and fewer uncertainty statements when feeds were available, they sent about similar amounts of content-related messages. Hence, a key impact of the short-message feed feature on communication is that it keeps communication more focused on task.

We argued that keeping learner communication more focused on the task could be either beneficial or detrimental for learning. Our results show that the benefits dominate. Specifically, we found that learning outcomes were better when learners sent fewer social messages and when they received fewer uncertainty statements from their team members. Importantly, our mediation analysis showed that the amount of social communication sent by the learner and the amount of uncertainty statements received from team members mediated the positive effect of the availability of feeds on learning outcomes. We offer the following interpretation of these findings. When learners read uncertainty statements from their team members, this has two effects on learners. First, these statements impose additional cognitive load on learners, which hampers the cognitive processing of content-related information. This is in line with cognitive load theory, which suggests that content should be presented in a form that is as simple and concise as possible (Mayer and Moreno 2003; Sweller et al. 1998). Second, when learners read uncertainty statements from their team members, satisficing norms are established, leading to lower aspiration levels in the team. Learners may then perceive it as legitimate to reduce their own cognitive efforts on the task, leading to weaker learning outcomes. In a similar vein to uncertainty statements, the learner's social communication may indicate and reinforce satisficing norms. When choosing to talk about issues outside task domain or when praising or thanking team members, learners express and reinforce the view that the current work products are satisfactory and that no further cognitive efforts for improving them are required. Reduced cognitive efforts result, in turn, in reduced learning outcomes.

It is insightful to note that our finding of a negative correlation between team members' uncertainty statements and learning contrast with the findings obtained by Sangin et al. (2011), who attributed a beneficial role to uncertainty statements. Specifically, they examined how a knowledge awareness tool affects collaboration in teams of two who synchronously worked on a concept mapping task over 20 minutes, using a vocal conferencing tool. They found that the knowledge awareness tool sensitized learners for the fragility of their knowledge and thereby triggered greater amounts of uncertainty statements, leading to more elaborative talk and better learning outcomes. It is possible that uncertainty statements had different effects in their study and in our study. Uncertainty statements may invite a more elaborative conversation in clearly delineated, short, synchronous conversations where learners strive to converge on a shared understanding within given time. But uncertainty statements may also give rise to satisficing

norms in settings where team members collaborate asynchronously on projects over longer time (three weeks in our field experiment) and make autonomous decisions about the amount of efforts they invest.

It is also interesting to contrast our finding of a negative effect of the learner's social communication and an insignificant effect of team members' social communication with the emphasis on social communication in CSCL research (Kreijns et al. 2003) and with the strong evidence of the importance of social (or interpersonal) processes both for learning (Van den Bossche et al. 2006) and for team performance (Bradley et al. 2003; Mathieu and Schulze 2006). We suggest two explanations for these discrepancies. First, the participants in our study may have been able to establish basic interpersonal relationships without requiring high amounts of social communication. It is possible that features of the SMP such as photos, profiles, and the feed allowed the teams to establish some sense of cohesion that did not require high amounts of social communication. Indeed, back in 2003, Kreijns et al. (2003) recommended enhancing collaborative learning environments with features that promote interactivity and social presence, suggestions that one may see addressed through the feeds, photos, and profiles features of contemporary SMPs. It appears thus that feed-based SMPs may make communication in collaborative learning less social but also compensate for reduced social communication by offering other social features. Second, social processes matter to a great extent when team members expect to work together with other team members in the future but less so in shorter one-off collaborations (Bradley et al. 2003). Although our field setting involved a longer collaborative tasks than in laboratory CSCL research, a one-off collaboration project over three weeks may not be long enough to warrant the investment into social processes by the team members.

Contributions

Our study makes three important contributions to CSCL research. First, we demonstrate that the short-message feed features of SMPs can have a positive effect on learning outcomes in collaborative learning settings. Confidence in this finding stems from our rigorous field experiment where we used two otherwise identical technological conditions that differed only in the availability of feeds. This helps CSCL research move beyond a more course-grained level comparison at the tool level where students using a tool (e.g. Twitter) are compared to students not using it (Junco et al. 2011). Second, we provide evidence on the mechanisms through which short-message feeds affect learning outcomes in collaborative learning teams. Using an extensive set of control variables, we show that short-message feeds affect learning by helping to focus learners on the task, rather than by increasing learner engagement. More specifically, our mediation analysis suggests that reduced social messages sent by learners and reduced uncertainty statements received from team members can explain the positive effect of short-message feeds on learning outcomes. This goes beyond existing research on the effects of SMPs on learning, which does not provide mediation analysis results (Junco et al. 2011). To the best of our knowledge, our paper is also among the first to show that short-message feeds can result in reduced social communication and in reduced uncertainty statements. Third, our study adds to the broader research on the roles of uncertainty statements (Sangin et al. 2011) and of social communication (Kreijns et al. 2003) in collaborative learning. Specifically, we show that uncertainty statements received from others and social communication sent by learners can also hamper learning, calling for research to examine in greater depth the mechanisms through which these types of communication affect learning in positive versus negative ways.

The key practical implication of our study is that higher-education teachers and learning environment designers should consider the use of SMPs with short-message feeds for collaborative learning tasks in team settings, in particular for tasks that require communication over longer periods such as several weeks.

Limitations and Future Research

We note a number of limitations of our study. First, while we examined mediation effects through behavioral constructs such as content-related communication and social communication, it would be insightful to examine cognitive or motivational constructs such as cognitive load, satisficing norms, or commitment. Future research could measure such potential mediators through a survey. Second, we showed the benefits of feed-based SMP in one particular setting using one particular task. Since team interaction patterns may depend on the nature of the task, on the size of the team, and on many other factors, future research may examine the consequences of feed-based SMP use in a greater variety of settings. Third, the participants in our study used the SMP for the work on one collaborative project in one course only. Future research may examine settings where learners use SMP for multiple projects or multiple

courses, settings where issues of information overload and technostress may be of heightened importance (Maier et al. 2015). Fourth, while we experimentally compared SMPs with and without short-message feed, we did not compare a SMP with short-message feeds to a SMP with feeds of unconstrained length. Hence, our results do not allow isolating the effects of the message size restriction from the effect of the availability of a feed. This remains future research.

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