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RESEARCH ARTICLE

A sociocultural approach to using social networking sites as learning tools

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Abstract

This paper focuses on evaluating a socio-cultural activity design (SCAD) model for using discussion-based social networking tools as a means to support the development of an online community of learners. Participants included 38 undergraduate students enrolled in a human-centered design course at a large, US university. The SCAD model includes concrete markers for identifying expected interactional, communication patterns for a community of learners. In order to examine the utility of our model we asked, (RQ1) to what extent do social network patterns coincide with expected outcomes for a community of learners; (RQ2) To what extent do students' cognitive activities in the environment match expected outcomes for a community of learners. To answer these questions, we conducted social network and content analysis of 503 posts in an online discussion-based social networking tool. We examined the overall sophistication of posts as well as changes in posting behavior over time. Findings suggest that use of the SCAD model facilitated processes associated with a community of learners, as students took over responsibility for the discussions over time, maintained strong connections with multiple peers, engaged in meaningful conversations about course content, and increased the sophistication of cognitive activity over time, even after instructor faded from the environment. However, findings also suggest more support is needed for online argumentation practices.

Keywords Communities of learners · Learning with social media · Social network analysis · Higher education · Computer science education

Human-centered design is a methodological approach within the field of Human Computer Interaction (HCI) that requires diverse knowledge and expertise. In order to learn how to engage in human-centered design, students need to engage in activities that require them to think like designers: to critically evaluate artifacts in the real-world, think about user needs, and understand cognition, emotion, resources, markets, and how all of these variables lead

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to the design of innovative solutions (Norman 2004; Preece et al. 2015; Rosson and Carroll 2002).

Instructional methods that emphasize student-centered learning have the potential to allow students to become more active participants in the learning process, but oftentimes students are more accustomed to traditional models where the instructor transmits knowledge. Transmission models of teaching continue to be pervasive in higher education (Kane et al. 2002; Murray and MacDonald 1997). It is quite common for the majority of college instructors to spend most of their class time lecturing (Ebert-May et al. 2011). Thus, students' expectations, shaped by their past experiences, can create obstacles for those instructors that aim to change existing practices (Engerström 2000). This situation makes it difficult to introduce more progressive, student-centered instructional models, such as the development of a community of learners (Bielaczyc and Collins 1999; Brown and Campione 1996; Rogoff 1994). The use of online discussion-based social networking tools could help to mitigate this problem, but specific design-based techniques to help students use these tools effectively to build an online community remain ill-defined.

In this paper, we build on learning theories to develop a socio-cultural activity design (SCAD) model for integrating discussion-based social networking tools to promote the development of a community of learners. Towards this aim, we draw on research literature to identify types of behaviors associated with a community of learners and articulate a model to help instructors effectively integrate and evaluate the use of discussion-based social networking tools for the purpose of developing an online community of learners. To test our model, we implemented it in an undergraduate HCI course and examined the form and function of online discussion-based interactions using mixed methods. In doing so, we were able to triangulate findings and show the potential benefit of using the SCAD model.

Theoretical framework

Our perspectives on how and where learning happens is largely influenced by sociocultural perspectives on learning (Lave and Wenger 1991; Stahl 2006; Vygotsky 1978). We believe that learning takes place through a combination of discourse and interaction with people and cultural tools as part of a dynamic activity system. Moreover, we focus on learning as it occurs in participatory processes. As such, we do not measure learning by conducting pre/post-tests of students' retention of knowledge, but rather examine whether students' discourse processes change over time to align with community goals and values.

We take a pragmatic approach to educational design that draws on theories and methods as a means to solve problems that interfere with desired learning outcomes. In the current work, we tackle problems associated with the development of communities of learners by incorporating a discussion-based social networking tool into a project-based course.

Related literature

Discussion-based social networking tools in education

Social media sites are prominently used in educational contexts, but it is rare to find studies that rigorously examine how they are used, the types of discourse that ensue, or whether they succeed in achieving key purposes and processes associated with communities of

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learners. In a review of social media use in higher education, Tess (2013) concluded that evidence and support for shaping social media in the service of learning are lacking.

In this paper, we focus on studies on the use of a specific type of social media: discussion-based social networking systems. Building on a definition provided by Leonardi et al. (2013), we define discussion-based social networking systems as web-based platforms that allow people to (1) communicate messages with specific people on the network or broadcast messages to everyone in the network; (2) explicitly indicate particular people in the network as communication partners; (3) post, edit, and sort text and files linked to others; and (4) view the messages, connections, text, and files posted, edited, and sorted by anyone else in the network, at any time of their choosing.

Though there are a variety of studies that examined learning benefits or outcomes of discussion-based social networking environments, there are many limitations associated with these studies. Specifically, such studies largely relied on self-reported learning benefits (Arquero and Romero-Frías 2013; Graham 2014; Ebner et al. 2007; Kalen et al. 2014), forms of online interaction that can be easily assessed, i.e., frequency of total posts, number of participants (Liu et al. 2016), or measured individual learning outcomes (Barak and Rafaeli 2004). None of these studies actually examined the discussions that took place or the ways that students interacted with each other to see whether these processes aligned with the development of a community of learners, which makes it difficult for instructors and researchers to fully understand how discussion-based social networking systems should be implemented to promote communities of learners.

Earlier studies examining course-based, threaded discussions argue that discussion quality is dependent upon the extent to which there is ongoing cognitive presence of the instructor in the environment (Kanuka and Garrison 2004). We believe that if properly trained, students can maintain high-quality, content-related posts even with the absence of instructor cognitive presence in the environment. Like any tool designed to mediate thinking and social activity, the potential learning benefits associated with the use of a sociotechnical tool are dependent on how the learner is taught to use the tool. What students perceive to be the goal of tool-use will impact the quality of discourse that ensues. This is especially true when the tool is used in educational contexts.

In our own previous work, we integrated discussion-based social network technology as part of an iterative course redesign project to address a lack of deep engagement with course content in an undergraduate course (Borge and Carroll 2010; Carroll et al. 2015). The goal was to use the technology to create a learning community where students could discuss course content, help each other learn, and complete their course projects. The instructor (the first author) moderated the discussion space by posting questions each week and responding to students. In the discussion environment, students discussed course content, but students did not initiate many questions nor were there long threads of conversation. The primary pattern that ensued in the discussion space was that of a question-response pattern: the instructor would pose questions or share resources and students would respond to those questions or like the resources. Students' posts rarely extended each other's responses and the instructor was the main contributor to the community, with the most connections with community members. This was not the desired outcome we intended for the use of the social networking environment; we wanted to create a community of learners where students take responsibility over the community, lead threads of inquiry, and create content as they work to complete a real-world project. So, we turned to research literature to better understand the needs and expectations of a community of learners and to devise a design model that would better meet the needs of students and help them learn how to use the tool to develop and sustain a community of learners.

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Understanding the desired outcome: development of a community of learners

A number of scholars have defined the processes aimed at increasing deliberate engagement within communities of learners (Bielaczyc and Collins 1999; Brown and Campione 1996; Engle and Conant 2002; Scardamalia and Bereiter 1991). Engle and Conant (2002) argued that in a community of learners, students must demonstrate productive disciplinary engagement. Broadly defined, productive disciplinary engagement involves active participation from the majority of community members to discuss content-based ideas leading to improvement in members' understanding of a domain. Engle and Conant (2002) synthesized the various elements of a learning community into four guiding principles: problematizing, authority, accountability, and resources.

Authority

Authority refers to providing students with opportunities to identify problems or questions they want to pursue and positioning students as active stakeholders and contributors to the learning process, to the extent that different community members may serve as experts on a specific topic or domain. As Engle and Conant (2002) explain, authority puts students in the role of knowledge creators rather than knowledge consumers. Handing over authority in this manner requires the instructor to shift from the role of central knowledge authority to a facilitator of knowledge-building activities, while students move from the periphery towards central contributors of ideas for the community (Lave and Wenger 1991; Papert 1993).

Lave and Wenger (1991) describe this shift in participation as a move from peripheral to central participation. They argue that most novices may begin as legitimate peripheral participants: observing and occasionally questioning activity, but relying on the instructor as the central authority and provider of information. However, they argue that learning communities allow for a shift in authority and central participation over time as community members become more knowledgeable and increasingly responsible for sustaining knowledge-building practices within the community.

Problematizing

Problematizing learning content has the goal of adding complexity to the learning task by introducing uncertainty, controversy, or highlighting discrepancies in what is known (Hiebert et al. 1996; Reiser 2004). As such, problematizing increases the likelihood for students to engage in sensemaking activity through argumentation and in higher-order cognitive activity. Helping students to engage in productive argumentation can lead to a variety of beneficial learning outcomes (Baker 1999, 2003).

Accountability and resources

Finally, accountability and resources refer to how we position students to respond to others' ideas within the community and what resources we provide for students to foster the development of a learning community and develop productive disciplinary engagement. Specifically, accountability refers to creating a learning environment where students have responsibility for maintaining community values and promoting intellectual work. However,

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maintaining the values and adhering to the guiding principles is difficult, because students often do not have the strategies to ask good questions, promote high quality discourse, or advance knowledge (Reiser 2004). This is why it is important to provide resources to supplement domain knowledge and guide participation, and technological tools to support ongoing discourse.

To develop a community of learners, we focus on the important dialogical processes in the discussion community. We propose that the literature supports four primary dialogical patterns associated with social and cognitive process outcomes:

- Social: a shift in participation occurs over time, where the students shift from peripheral to central participants, when they no longer depend on the instructor to be the central authority or provider of information.
- Cognitive: student engagement in rich conversations with each other where they work to make sense of course content together and complete projects.
- Cognitive: students assume the role of knowledge creators and use the discussion-based tool to engage in thinking about and problematizing course content.
- Cognitive: students work to meet community goals by taking responsibility for maintaining community values and promoting intellectual work.

These are important social and cognitive process outcomes that we would want to see resulting from the use of a discussion-based social networking tool; they are to show that students have learned to use the tool effectively and have developed and maintained an online community of learners. However, socio-cultural theory posits that there are many potential factors within an activity system (classroom) that could prevent these desired outcomes from coming to fruition. These socio-cultural factors can influence how learners in that system will interact with a learning object, i.e. an online social media technology. These factors include cognitive and physical tools such as previous experience, scaffolds, and software features. Other factors include rules and expectations of the community, how the labor to carry out tasks and run the community is distributed, and the values of the community.

Traditional instructional models, such as those proposed by Joyce and Weil (2005), do not account for the dynamic nature of socio-cultural systems. They are focused on helping instructors to learn how to carry out concrete practices in a linear fashion, which is helpful for straightforward tasks, but may not be as helpful for the development of complex systemic processes. Traditional models also prioritize content-based learning outcomes, rather than process-based dialogical outcomes.

We argue that it is necessary to account for socio-cultural factors as part of design and ongoing classroom instruction in order to optimize online discussion quality, where quality is defined as discussion processes associated with communities of learners. Moreover, these factors need to be considered as part of course design prior to implementation and as part of instructional methods during implementation with knowledge of what the desired outcome, i.e., discussion processes, should look like in a concrete and measurable way.

A socio-cultural activity design (SCAD) model

In this section, we propose a socio-cultural activity design (SCAD) model, based on our prior work and the literature on socio-cultural factors, to address important considerations when using technology to develop online learning communities (see Table 1). This model

Table 1 A socio-cultural activity design (SCSD) model for developing an online community of learners

Activity system factors	Optimizing online discussion processes		Expected outcome
	Design considerations prior to implementation	Instructional considerations during implementation	
Distribution of labor	Provide students with agency over the community by devising tasks where students learn how to lead discussion and moderate the community	Require students to take on responsibility for moderating discussion and include students in ongoing decision-making about the community	A shift in participation occurs over time: the instructor fades as the main contributor and multiple students take on the role of moderating and leading inquiry
Values	Align course syllabus language and activities to promote collaboration and discourse and create guidelines to articulate community values to the learners	Promote collaboration and knowledge building discourse as central to learning	There is variation in posting behavior similar to naturalistic conversation. There is evidence that students read, reply, and synthesize others' posts and create long threads of inquiry rather than question-response pairings
Tools	Select a technology that provides opportunities for community building and cognitive resources to help students know how to carry out and regulate desired activity through the technology	Provide a dialogic space to discuss ideas related to content; have instructor model desired activity to connect course content to real-life practice, share resources, ask for help understanding topics, and reflect on their learning	Most student-led discourse is content-based, which includes a variety of cognitive activity, promotes higher-order thinking processes, includes reflection, and shows evidence of argumentation stemming from problematization of content
Rules	Create grading criteria that hold students accountable for contributing to community	Ensure all adhere to course expectations and requirements related to tool use and participation in online discussion	Students maintain community values and promote intellectual work even after instructor fades

Note that research questions are mapped to the expected outcomes under each activity node. In a dynamic activity system, we expect that some of the outcomes will not, in practice, map neatly to a single node, but instead emerge dynamically from interaction within the larger activity system. The research question mapping is helpful for understanding the design of our study

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can help instructors understand how to (1) address sociocultural factors that students interact with in a systematic way, (2) describe when and how different factors should be attended to, and (3) provide concrete markers for assessing the success of an implementation.

Drawing from activity theory (Engerström 2000; Jonassen and Rohrer-Murphy 1999), we aligned the different socio-cultural factors with the ways we wanted students to interact with technology to produce the desired outcome. This meant ensuring that the ways we distributed labor over the community, the tools we provided, the rules we created for holding people accountable, and the values we promoted all contributed to promoting a community of learners and did not create unwanted tensions. For example, if we wanted students to see themselves as important contributors to the community, but the instructor controlled all aspects of the course by leading classroom and online discussions, this would have created tensions between our existing practices and our desired outcome. To reduce the likelihood of such tensions, we revised the design of the course, designed new tools, and revised instructional methods so as to account for socio-cultural factors before and during implementation.

Our model (Table 1) includes activity system nodes as rows and considerations for design and instruction, as well as expected outcomes, as columns. The last column of this model synthesizes research literature that we discussed in the previous section as a set of expected process outcomes in the online discussion-based social-networking system.

Addressing sociocultural factors as part of instructional design prior to implementation

Different types of tools, rules, and expectations can help guide students as they participate online and take on differing roles. These tools include the selection of an appropriate online discussion space that would protect learner privacy and provide features that could allow an online community to develop. For example, private enterprise social networking tools, with servers housed in the university, provide more privacy than public, online tools like Facebook that make money off of user information, and their ability to use this information to manipulate users into carrying out desired behaviors that are oftentimes disconnected from the promotion of positive learning outcomes.

To ensure that students understand the aim of the course, the value of collaboration, and have the space to engage in laborious collaborative activities, instructional designers must examine the whole of the course with regards to the demands placed on students and reduce existing demands that may not promote desired values before adding new demands that do. For example, individual homework activities can be cut and replaced with online discussion activities. It may also be necessary to examine how participation is defined in the course to ensure that it is defined as being active in the classroom, in the online discussion-based environment, and as helping to develop and maintain the online learning community. It is important to ensure that this type participation makes up a sufficiently large part of their grade so that students perceive this activity to be an important part of the course.

Also, it is necessary to design cognitive tools to help students understand how to participate in the online discussion; otherwise, students may revert to internal schema they have for online participation. For example, many online students are required to post a summary of readings and a response to others' summary. Without any scaffolds to push them to do otherwise, students may use this type of posting strategy rather than engage the types of sensemaking conversations we want them to engage in. An example of a useful cognitive

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tool that can help to instill community values is a guide to help students understand the goals and values of the community and provides examples of how to meet these goals in concrete ways. Such guides should provide students with examples of different types of posting behaviors that uphold community values so that students can refer to the guide when trying to figure out what to post.

All of these changes are made with the intention that when individuals read the syllabus and interact with the new tools, they get a sense of the course as being dependent on collaboration, discourse, and active learning in the community.

Addressing sociocultural factors as part of instructional methods during implementation

Addressing socio-cultural factors as part of design prior to implementation provided the foundations for the development of a culture and value system aligned with the culture of a community of learners. However, students still need to learn how to carry out online behaviors to meet and maintain those standards. To help students, the instructor can model, reflect on, and coach appropriate behaviors over time so students can internalize the value system and participation schemas over time.

An important consideration is how to support tool use during implementation. Providing a dialogic space where students can engage in discussion around course topics is not enough. The instructor can set the tone of the environment by modeling posting behavior and their thinking around posting behavior and then slowly fading from the environment. This can be accomplished by having the instructor be primarily responsible for developing and maintaining the community (moderating) for the first 3–4 weeks of online course discussion. During this time, the instructor can model desired posting behaviors as defined by the online participation guide, using a variety of different posts to encourage sensemaking activity, the articulation of thinking processes, and how to admit that they do not understand something in the reading. The instructor can create meta posts where they reflect on their previous posts, how they generate questions, how they evaluate their moderating, what they think of the community's processes and the moderation process. As they model behavior and articulate their thinking, the instructor can refer to the participation guide to remind students to use the resource to ensure that everyone follows the community guidelines. Then, after the 3rd or 4th week, the instructor can shift moderating responsibility to student teams, by assigning teams to moderate different weeks. All the while, the instructor would continue to promote collaboration and knowledge-building discourse during in-class sessions. Over the next 5 to 6 weeks, the instructor would aim to slowly fade from the environment.

Expected outcomes

The expected outcomes described in the SCAD model are drawn from our synthesis of the cited literature and can help us to assess to what extent a learning community actually develops over time. For example, if the model proves effective, we would expect to see changes in the social network patterns of the online community over time that coincide with the expected behaviors for a community of learners.

In the beginning, we would expect instructor to be a central participant: responsible for leading the majority of discussions, to post more than students and be more a more socially connected participant that the students. At the same time, students would be more likely to

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depend on the instructor for information and feedback and therefore have more interactions with the instructor than with their peers. Students would likely engage in less varied posting behavior as they simply respond to instructor queries or post questions to simply fulfill the posting requirement.

As the course progressed, we would expect to see the instructor slowly move to the periphery. Students would move towards central participation, gradually becoming primary contributors, participating in more varied social interactions, i.e. producing lines of inquiry and receiving large amounts of responses from others. We would expect students to show evidence of valuing others' contributions by reading, replying to, arguing against, and synthesizing other's posts, creating long threads of inquiry and discussion rather than simply creating question-response type posts and showing a larger variety of posting behaviors among students.

If the model proves effective, we would expect to see evidence of cognitive activity indicative of high-quality disciplinary engagement in the environment. This would entail the majority of student-led discussions to be content-based, include a variety of different types of cognitive activity, promote higher-order thinking, and show evidence of argumentation stemming from problematization of course content. We would also expect students to maintain community values and promote intellectual work after the instructor fades from the online environment.

To test the utility of the SCAD model, we ask the following research questions:

RQ1: To what extent do social network patterns coincide with expected outcomes?

- RQ1.1 (Examining distribution of labor): To what extent do social network patterns show shifts in participation and interconnectivity over time?
- RQ1.2 (Examining values): Is there an increase in variation of online posting activity over time?
- RQ1.3 (Examining values): Is there evidence of rich discussion threads, where students read, reply, argue against, and synthesize other's posts?

RQ2: To what extent do students' cognitive activities in the environment match expected outcomes for a community of learners?

- RQ2.1 (Examining tool use): To what extent do students discuss course content and engage in high levels of thinking in the environment?
- RQ2.2 (Examining tool use): To what extent do students problematize course content by engaging in argumentation around course content?
- RQ2.3 (Examining adherence to rules): To what extent does students' quality of posts remain high when the instructor fades from the environment?

Methods

Study design

The overall methodology of the reported study was design-based research (Brown 1992; Collins 1992; Collins et al. 2004). Design-based research is iterative and can be reported at

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various stages and levels of scale. In this paper, we focus on reporting the second iteration, after making modifications to our initial instructional approach.

Participants

The study participants were junior and senior college students enrolled in an introductory human-centered design course at a large US university. Students were divided into nine teams of five-to-six students. There were 42 students in the course. Thirty-eight students consented to letting us evaluate their online behaviors as part of collective social network and content analysis of the general quality of posts. Thirty students consented to having their individual posts analyzed or used in publications.

Course design

Course structure

The course was structured in a way that students could learn about course concepts and practice and apply them as part of authentic project-based, collaborative work (for example of course syllabus see https://sites.psu.edu/mborge/files/2019/10/HCD-Example.pdf). Students were assigned to design teams of five-to-six members at the beginning of the course. In the first eight weeks, students read the first eight chapters of their textbook, *Interaction Design: beyond human–computer interaction* (Preece et al. 2015), one per week. During this time, teams worked on a design challenge each week connected to course concepts as a means to apply what they learned that week. Halfway through the course, students picked their own design challenge, a project that could help the local community, and were expected to complete a seven-week, design project to demonstrate their ability to apply the core concepts and techniques covered in the first half. These projects were evaluated using real-world HCI design criteria, which were provided for students.

The class met three times per week for 50-min sessions. On the first day of the week the instructor took 20 min to go over difficult concepts, on the last day of the week the instructor used 15 min to review the week and answer questions. During the rest of class time, teams worked on design challenges. During these work sessions the instructor and the learning assistant would walk around the class and check in on teams.

In place of additional homework, students were asked to post on Yammer once a week for 12 weeks to discuss course topics. Students received credit for any type of post and were not graded on the quality of their post. Yammer participation was only part of total participation grade and accounted for 10% of total grade.

Implementation of the SCAD model

We followed the model prior and during the course to attend to socio-cultural factors. Prior to implementation, the syllabus, course activities, and grading rules were revised. We selected an appropriate discussion-based tool (described in the next section) and developed a guide to help students understand the major aims for participating in the environment. The guide helped to ensure that teams understood how to uphold community values and post a range of high-quality questions. It explained our vision for our online community and provided students with examples of how they could help us meet these goals in our online discussion space (for full guide see https://sites.psu.edu/mborge/files/2019/10/

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YG.pdf). The specific community goals shared with our students in the guides were as follows:

1. Developing community
2. Making the environment useful for learners
3. Pushing for deeper analysis of course content
4. Maintaining a safe environment where students feel free to take risks and admit when they do not understand.

For each goal, we provided an explanation of what it meant and a concrete example of a posting behavior that could be carried out to meet the goal (see Table 2).

We reexamined the syllabus and modified classroom rules associated with grading and participation to increase class participation from 15 to 25% of the total grade. We reduced individual homework activities and replaced them with online discussion activities. We defined participation as being active in the classroom, in the online discussion-based environment, and as helping to moderate the discussions that occurred in the online discussion environment. We then revised the syllabus to emphasize the importance of sensemaking discussion and collaboration.

We followed the model during the course. The instructor began by modeling posting behavior. In the first 4 weeks of online course discussion, the instructor was solely responsible for moderating discussion activity. During this time, the instructor modeled desired posting behaviors as defined by the four-page moderation guide; the instructor used a variety of posts to encourage sensemaking activity and articulation of thinking processes, and reflection on their discussion processes and the moderation process. The instructor also referred to the moderation guide to remind students to use the resource to ensure that everyone followed the community guidelines. Then, the instructor slowly shifted moderating responsibility to student teams. Student teams were then randomly assigned to moderate the online environment, starting in week five. Meanwhile, the instructor continued to promote collaboration and knowledge-building discourse during in-class sessions. Over the next 6 weeks, the instructor slowly faded from the Yammer environment.

The discussion environment

We chose to use a discussion-based, social networking site run by Microsoft and licensed by the students' university, called Yammer. Yammer is designed in many ways similar to Facebook, but does not allow public access (see Fig. 1 for screenshot of the Yammer environment); only those associated with the university are allowed on the network. The site allows students to embed pictures, articles, or other media as part of their posts. Others can then respond to posts and embed media in their response if so desired. Students can also respond to multiple people in a thread by tagging those to whom they are responding.

Data collection and analysis

Data corpus

Each student action in Yammer was recorded in a log file. The log data, along with texts of posts from the Yammer environment, were extracted and exported to Excel spreadsheets. There are three types of posts in Yammer: original posts, replies, and replies to

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Table 2 Goals, objectives and examples for creating a learning community presented to students

Goal type	Objective	Example
Community	Make students feel welcome	Go out of way to read what people write and like posts
	Make students feel valued	Point out when really good posts are presented
	Make students feel necessary and impactful	Ensure that the community grows and evolves in ways students desire as long as it meets the goals
Utility	Provide students with resources	Tools or examples
	Provide students with opportunities to extend thinking	Share ideas, question content, make connections to real world, take thinking out of classroom
	Provide students with opportunities to reflect on understanding	Compare difficult concepts, push thinking
Practice	Keep content relevant	Make sure yammer content connects to weekly course content
	Keep content professional	Try to encourage appropriate content
	Keep a range of content complexity	Provide readings and examples from a range of academic and professional sources/ media
Psychological safety (Edmondson 1999)	Make students feel safe to share information and admit they do not understand	Do not judge rightness or wrongness, but instead prompt thinking
	Show students mistakes are valuable	Show it is okay to be wrong by describing your own mistakes and how they helped to shape new understanding
	Set guidelines for constructive criticism	Encourage people to propose different points of view in a positive way

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Fig. 1 Screenshot of the course Yammer site

replies. All the posts were timestamped. Each *original post* was the start of a new conversation. The data included the name and a Unique ID for each poster, and a Thread ID for each new conversation. When students replied to original posts, their response would include a Response ID associated with the corresponding Thread ID. This allowed us to see who replied to whom and identify different threads of conversation. The data also allowed us to see *replies to replies*. These posts contained the users' unique ID, as well as a Replied to ID that matched the unique ID of the person they replied to; the thread ID matches the unique ID of the original poster. In this paper, the term "post" refers to original posts, replies, and replies to replies. The term "original post" refers to the top-level post that starts a new conversation thread. The data includes the entire content of what was being shared and links to any additional articles or materials that students attached to the post. This allowed us to analyze the quality of the content.

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Data preparation for social network analysis (SNA)

To understand interaction patterns, the data was exported to an SNA tool called Gephi. In total, 503 posts were analyzed in this software visualization tool (Gephi). Gephi facilitated creating visualizations to capture activity patterns: people are represented as nodes and lines between nodes represent connections. To examine social interaction patterns over time, Yammer activity was split up into three time-points according to classroom activity. Time-point 1 (T1) included the first 4 weeks of Yammer use, where the instructor moderated Yammer and modeled posting behavior. Time-point 2 (T2) included the following 4 weeks, when students began moderating Yammer to help students make sense of course concepts. Time-point 3 (T3), was a 5-week span, with 4 weeks of active Yammer activity (1 week was inactive due to spring break). Students began part two of the class at time point 2, moderated Yammer, and focused on helping each other make sense of course content and complete group design projects.

Social network analysis (SNA)

Social network analysis (SNA) is a technique for making sense of the social relations that exist within a community, network, or organization. In a collection of people, the social connections that exist between them can be quantified to illustrate "who's in the center of it all," "who's brokering between two subgroups," and "how 'tight' is this community". Statistically, these quantifications are referred to as "degree centrality," "betweenness centrality (aka brokerage)," and "network centralization," respectively. Sometimes this quantification can take a more narrative form with a preference toward quantitative or qualitative descriptions (Freeman 2004), but more often in the case of online communities, SNA is performed using the instances of communication acts or trace data in log files as representations or proxies for how and to what extent participants are connected with each other (Goggins and Dyke 2013; Goggins et al. 2013; Goggins and Petakovic 2014).

We connected our SNA of the learning community to the theories underlying our investigation and, in turn, the research questions we were pursuing. Conceptually, degree of centrality measures corresponded with Lave and Wenger's (1991) description of participation: low centrality indicates peripheral participation and high centrality corresponds with membership in the core. Direction of centrality referred to indegree, the amount of ties directed to a node (person), and outdegree, the amount of ties that a node (person) directs to others. Weight of connection was determined by the frequency of ties between nodes, with those having greater ties represented visually as having thicker, darker connecting lines. Finally, type of posts examines whether a post is directed out to community as in an original post, or specific members, as in a response to a post.

Classification and assessment of posts

We also assessed the quality of students' post content. We excluded 98 instructor posts from the analysis, and classified the remaining 405 student posts according to the topic of the discussion and whether it was connected to course content. Posting behavior was categorized according to the type of cognitive activity represented in each post. Level of cognitive activity was used as a means to assess the quality of posts in the social media environment, which were intended to be informal, content-oriented conversations. Students

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were not expected to engage in formal scripted argumentation, make long posts summarizing course content, or adhere to a scripted way of interacting. They were asked to talk about course content as they saw fit.

To develop a valid and reliable coding construct, we initially based coding on identifying differing levels of cognitive activity that coincided with previous work (Borge et al. 2012). We then compared the different types of cognitive activity to research from communication analysis and sensemaking literature to ensure that higher-level posts provided evidence for higher-level activity (Convertino et al. 2009; Dyke et al. 2013; Pirolli and Card 2005). We did not assess writing quality, but rather the level of cognitive engagement with course content that students displayed in the post. We held meetings with research assistants to identify behaviors and distinguish between codes in order to refine the coding construct (see Table 3 for the final coding construct).

Our coding construct included five levels of content-based posting behavior. A level 0 post, the lowest order post, is off-topic and therefore not related to course related sensemaking. A level 1 post demonstrates sharing behavior, where students share an opinion or fact, but do not provide any evidence or rationale to support it. A level 2 post extends course content by providing additional resources, i.e., readings, videos, visualizations, etc., related to the course content in that week. In doing so, students demonstrate that they sought out additional information about course content, but did not demonstrate that they read them, thought about how the resources were connected to course content, or that they read previous posts. A level 3 post demonstrates that students read previous posts and took the time to think by asking clarification questions or rephrasing ideas, demonstrating attempts at comprehension. A level 4 post goes beyond comprehension to show evidence of synthesizing course ideas with real-world examples or other student posts. However, it does not show any evidence of carefully analyzing ideas about course content. A level 5 post is the highest, content-based cognitive level. It shows evidence of analyzing course content by making claims and counterclaims, supporting these claims with evidence, rationale, or weighing different ideas. Thus, level 5 posts demonstrate aspects of argumentation and problematization of course content as aligned with the principles of learning communities.

Higher-level posts can include attributes from lower-level posts, but lower-level posts cannot contain attributes of higher-level posts. Post levels 1–5 exclude posts containing metacognitive activity. Posts that include aspects of planning, monitoring, reflecting on, or revising thinking processes are classified as metacognitive posts. Metacognitive posts are still considered higher-order processes, but not included on the content-based cognitive scale.

Once the coding construct was finalized, the first author and a research assistant analyzed 20% of the data. The inter-rater reliability was high (Landis and Koch 1977): $r = .89$, $p < .001$; Kappa = 0.78, $p < .001$. Disagreements were discussed and resolved. The research assistant then coded the full dataset.

Evaluating argumentation quality

Of the 405 posts, 107 were level 5 posts that contained some form of argumentation. Of the 107 posts, 10 original posts were excluded from the analysis because they were posted by student moderators who were expected to post high quality content. The remaining 97 posts belonged to 42 different discussion threads and were made by 31 different students. The argument-coding schema was adapted from a coding scheme for assessing the quality of small group collaborative discourse in synchronous online

Table 3 Coding construct for classification and assessment of posts

Levels	Definitions	Examples
0. Non-content related talk	Posts do not refer to course content or learning processes. May include organizing, coordinating, documenting, or deciding on classroom activity	1. Class today, we will work on chapter 2 2. Ha, this is funny, check it out! 3. I presented on my team today
1. Sharing (SHR)	Discussing content or facts w/o making claims that are supported by rationale or evidence. Includes no rationale, examples to real-world use, links or attachments to additional material, reference to previous reply, or reflection on their own thinking processes	1. I think this is a great example to talk about 2. This video was really helpful to me. I like how it talks about course content. Really cool 3. I took a class like that once. The instructor was really interesting
2. Extending (EXT)	Extending available readings or content material by providing links or attachments to additional content (video, article, concrete example, etc.) to help think about course content. May include level 1 behaviors but cannot include rationale, examples to real-world use, reference to previous reply, or reflection on their own thinking processes	1. [Link- no post content, but related to course content or discussion] 2. Here is an article explaining mental models. [link] 3. I thought this was funny, and helped me to understand mental models. [attachment]
3. Checking/revoicing (C/R)	Checking understanding, clarifying what someone previously said, or repeating/rephrasing (without adding new ideas). May include level 1 or 2 behaviors but cannot include new facts, opinion, rationale, evidence, examples to real-world use, or reference to previous reply, or reflection on their own thinking processes	1. What do you mean by design implication? 2. I'm not sure I know what that means but, I think it could relate to user experience 3. Tom's post: "We should think about a, b, & c", and then Bob's Post (a level 3): "Yes we should think about, a, b, and c, it is important to do so." (Reference to Tom's post with no new information)
4. Synthesizing (SYN)	Evidence that post is referring to a previous post and adding to the idea, or that poster is connecting a previous idea to a real-world example or a previous post that no one else has mentioned. May include level 1-3 behaviors but cannot simply repeat previous connections made by other posters, or include rationale, evidence, or evidence that poster is reflecting on their own thinking processes	1. I was thinking about user experience and found this great article about users and the new iphone and why their designs work. (Connecting to real-world) 2. When tom pointed out that design should be beautiful it made me think about the old versions of remotes and how much I hated using them. Once Tivo came out, I ignored all my other remotes. (Reference to Tom's reply + added info) 3. I agree that texting could affect your brain in a bad way [Todd tagged], but you could also find ways to use it as a learning tool

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Table 3 (continued)

Levels	Definitions	Examples
5. Interpreting (INT)	Connecting course content to other information and making a judgment about it or evaluating a claim. Claims or opinions MUST be supported with rationale or evidence, or they must show that they are weighing ideas against each other. May include level 1-3 behaviors but cannot show evidence of reflecting on their own learning or thinking processes	1. I think that Tim has a point because when you account for users' limitations you sometimes have to sacrifice how pretty something is 2. Requirements is one of the most important parts of the design process, because it lays the foundation for the rest of the development stages, and good requirements makes sure you focus on real user needs 3. Requirements is one of the most important parts of the design process. This article does a good job explaining why. It focuses on understanding the needs of users and the activity you plan to support
Metacognitive Reflection/awareness (MC)	Not discussing course content but thinking about or sharing awareness of their own learning or learning experiences as an object of thought. Reflecting on learning process or demonstrating awareness of learning process by articulating learning patterns or needs as learners. May include level 1-5 behaviors	1. I find that I learn best when I can talk about the content with someone 2. When I am studying for an exam, I often go back to think about those concepts I did not understand. Then I try to figure out how to improve my understanding of those concepts 3. I think that teachers need to do better to support how we take tests because I often do not understand the best strategies for doing well. I just never learned that

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discussions (Borge et al. 2018). The finalized coding scheme comprises four criteria scored on a binary scale to look for the existence of four critical argumentation behaviors: an alternative claim or idea, analysis of claims/ideas, uses of evidence, civil discourse (see Table 4).

The second author and a research assistant independently coded 30% of the posts for argument quality. Cohen's kappa range was from 0.65 to 0.71, $p < .001$; no kappa was computed for *professionalism* as all sampled posts were scored as '1' by both raters. Differences in the codes were resolved through discussion. The second author then coded the remaining 70% of posts.

Results

(RQ1) To what extent do social network patterns show shifts in participation and interconnectivity that coincide with expected outcomes?

Shifts in social network patterns over time

The visualizations in Fig. 2 illustrate posting behaviors that occurred in the first 4 weeks of class (T1), the next 4 weeks (T2), and the last 4 weeks (T3). Nodes indicate students who contributed posts. The size and relative positioning of nodes indicates frequency of posts and degree of centrality within the community, respectively. Lines between nodes indicate connections between people, meaning they received a post from or sent a post to another contributor.

SNA findings as depicted in Fig. 2 revealed two important patterns. The first pattern is related to the level of connectedness of students. Findings indicate that students were connected to multiple classmates through posting behavior. This is evident from the many connections between students in each four-week period. These connections indicate that students sent and received posts to multiple peers. The second pattern identified is related to authority and cognitive presence in the environment. Over time, the instructor moved from a central to peripheral participant, while students became more central participants. Figure 2 shows this pattern over the three time-intervals.

Degree centrality is shown by relative positioning in a social network diagram. People with more diverse and strong connections in the network, are represented as more centrally located nodes in the diagram. At T1 the instructor (with the alias of "II") was a central participant. She had a high degree of posting, shown by the size and dark color of the node. She had 21 diverse and strong connections, as shown by multiple dark lines connecting her to others in the network. At T2, "II" began to move towards periphery of the diagram. She had less connections, nine, as shown by the smaller size and lighter color of the node. She also showed a decreased number of strong connections, with two dark lines between her and AA and DD. At this time, several students started to become more central than the instructor. The central participants shifted from T2 to T3, but four, core members, AA, DD, L, G, remained strong and connected contributors throughout T2 and T3.

By T3, "II" moved to the periphery. Her node was quite small. She had only four connections, and only one of them was strong (between her and C). At the same time, students' posting behavior became more central to the network, showing more diverse and strong ties than the instructor.

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Table 4 Scoring criteria for

Scoring criteria	What is being evaluated	Examples needed to achieve score
Alternative claim or idea	Whether or not a person provides or asks for a counter claim or different perspective for a previously discussed claim or idea	Score of 1 if post includes an alternative claim/idea to an existing one (in a previous post within the same discussion thread), call for further evaluation of an existing claim/idea, and/or identification of problem(s) with an existing claim/idea
Weighing of options	Whether or not a person provides an analysis of different options, perspectives, or claims	Score of 1 if post includes justification of a claim/idea by discussing cost(s) and benefit(s) or pro(s) and con(s) of one or more claims/ideas
Use of evidence	Whether or not a person provides fact-based evidence to support rationale	Score of 1 if post includes justification of a claim/idea using identified, fact-based evidence (e.g., articles, books, website information, documentaries) to support its rationale
Professionalism	Whether or not a person uses language that is appropriate for professional settings: respectful, civil, and not potentially offensive.	Score of 1 if post includes language that is respectful and not potentially offensive; criticism (if any) is targeted at the claim/idea and not individuals who made it

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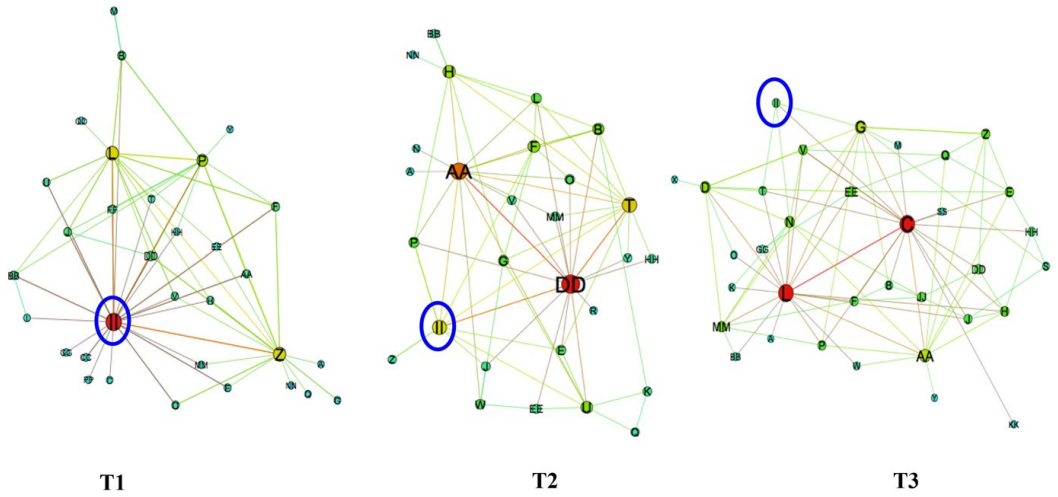

Fig. 2 Social network diagrams of discussion activity at three time-points: T1, Instructor (labeled "II" and is circled) leading and modeling; T2, students moderating to help each other understand course concepts; and T3, students moderating to help each other understand and complete personal projects

Variation of online posting activity over time

When we examined types of posting behavior that occurred over time, we found a shift in type of participation from T1 to T3, adding analysis of the direction of degree centrality and weight of connection, shown in Fig. 3. Figure 3 illustrates increasing diversity of participation across the time periods, with different people surfacing as recipients of broad interest (indegree centrality), and a growing number of students responding to others more, and more broadly (outdegree centrality) over time. This empirical change over the course's life suggests that students engaged in the types of interconnected conversation in the environment that mimic real-world conversational activity. The pattern displayed by participants contrasts with the more stilted, less natural question/response pairings that are common in online forums.

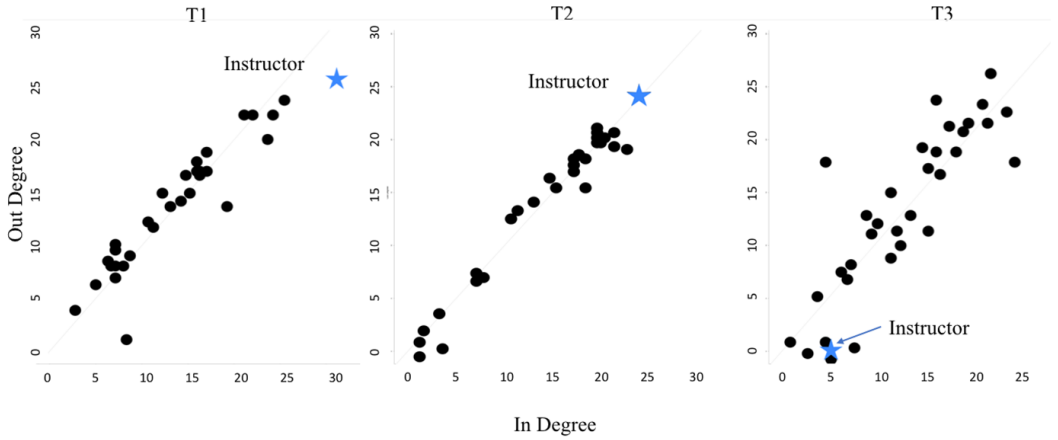

Fig. 3 This picture shows students' increasing diversity of participation roles across three time-points, from T1, leftmost, to T3, Rightmost; Instructor, II, (highlighted) produced and received the most posts at T1, received less post at T2, and produced and received minimal posts at T3

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Evidence of rich discussion threads

When examining the content of discussion threads, we identified 25 threads that contained substantial conversations containing five or more replies to original posts. To illustrate these interactions, we included an excerpt from one of the threads in Table 5, using pseudonyms for student names. These threads showed that students were reading, replying to, synthesizing, and arguing with previous student posts. On this particular week, students were reading about online privacy and security. Evan began the thread by attaching a link to an article in the Wall Street Journal that pointed out some questionable data collection practices among popular, well-known, and respected companies. Evan then asked the community whether anyone was nervous about the amount of information that companies could gather about them and how we could protect privacy.

Evan's post received 15 responses from 14 different students, one of which was Evan responding to a response. We included the original post and six responses as a means to illustrate the quality and form of conversations that took place in the thread. In the responses, students discussed their personal feelings about data collection, presented arguments for and against the collection of personal data, and made claims about what counted as violation of privacy-all while responding to or synthesizing previous posts in the thread.

The initial responder, Melinda, seemed concerned about privacy violation and suggested people have a level of control over what data is collected. However, as more students contributed and questioned assumptions about privacy and personal level of control (posts 3–6), Melinda changed her mind in post 7. When she shared another article that discusses types of personal, customer data Google apps shared with developers, she stated that "It is sending your name, address, and email to the creator of the app for no reason". She added that customers are not made aware of this data sharing, stating "there is absolutely no mention of this happening anywhere in the Google play store". Thus, she implied that there was a lack of control about how our personal information is collected and shared.

(RQ2) To what extent does students' cognitive activity in the environment match expected outcomes for a community of learners?

Course content-based discussion and levels of thinking

Course content-based discussion is defined as posts or replies related to core concepts and techniques of the class, as well as project related discussions. "Other" discussion included course management and metacognitive behaviors related to awareness and reflection of students' own learning needs, practices, or experiences. Of 98 instructor posts, 58 (59.2%) were related to course management, a type of "other" talk. In contrast, only 56 of 405 student posts (13.6%) were "other" and 349 posts (86.2%) were directly tied to course content. Most of the "other" posts included ones where students shared resources that challenged traditional learning models, discussed their own learning experiences, or coordinated classroom activities. Only one post (0.25%) did not deal with course content or student learning.

Five levels of thinking exhibited cognitive behaviors for content related discussions. Evidence showing less to more disciplinary cognitive engagement include: (1) sharing, (2) extending, (3) checking/rephrasing, (4) synthesizing, and (5) interpreting (see Table 6 for a list of exhibited behaviors and frequencies). Though "extending" posts were not ranked as highly as interpretation posts with regards to providing evidence for higher-order

Table 5 Excerpt of an inquiry thread that contained 16 posts, showing the original post and 6/15 responses

From	To	Post
1. Evan	All	With the large scale of data collection through technology today there are huge questions being raised about how cell phone providers collect user data. Whenever your smartphone is on it is constantly putting out data of your location, what apps you are using, and even what type of searches you do so ad placement will fit your interests. With all of this personal information being collected by big companies like Apple and Google, do you as a user feel nervous or violated in any way? What can we as users do to protect our information from these big companies? [link to article: Apple, Google, Collect User Data]
2. Melinda	Evan	I believe this absolutely is taking your privacy away. Your phone is transmitting data at all times and we don't know who can get access to this information. I personally turn off my mobile data and location services at all times except for the short time that I need to use them. I would say our privacy is violated but, it is not always in a malicious manner. We need to be careful to not leave this on at all times"
3. Tim	Melinda	You have a choice to opt into the Google tracking and all of it is anonymous. I don't know about the Apple side, though
4. Jason	Tim (but referencing a previous post not included in this excerpt)	I have no issues with data gathering. My only issue is how the data is used. When trying to find better ways to provide services to consumers this data can be useful. This is especially true for interaction design. The only worry I have is the one stated above in which the government accesses this data and uses it without permission. I am not sure that this has ever occurred but nonetheless I am still cynical about this and believe it is not completely out of the question that it could happen. I believe personal data about people should require authorization similar to how medical records have laws requiring rules for its disclosure
5. Rick	Tim	Regardless of your personal settings (what you think you are sharing and not sharing) your service provider can still always tell where you are based on cell towers. This doesn't bother me but I'm sure for some people in certain situations it could
6. Deshan	Evan (referencing Rick, & Jason)	Yes, I agree, the ability for others to gather our data, seemingly without our permission is in fact or should be a concern. Even if you change your settings to remove sharing data, they are still accessible. It should strictly be only available based upon user authorization just ask Rick and Jason have mentioned

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Table 5 (continued)

From	To	Post
7. Melinda	Evan	It was recently released that every time anybody bought anything in the Google Play store, Google's version of the app store, that all their personal information is being sent to the app creator. It is sending your name, address, and email to the creator of the app for no reason. There is no reason the creator needs any of this information and there is absolutely no mention of this happening anywhere in the Google play store. It is information leaks like this that we really need to be worried about. This information is coming without the developer even asking for it. [link to article: Google under fire for sending users information to developers]

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Table 6 Types and cognitive levels of posts exhibited by students in the Yammer environment

	Level/type	Percentage of posts (number of posts)
Non-content related talk (8.9%)	0. other talk	9.1 (37)
Content related talk (86.2%)	1. Sharing	9.1 (37)
	2. Extending	17.3 (70)
	3. Checking/repeating	1.7 (7)
	4. Synthesizing	31.6 (128)
	5. Interpreting	26.4 (107)
Learning centered non-content related talk (4.7%)	MC. Metacognitive reflection/awareness	4.7 (19)

sensemaking thought, they were nonetheless an essential part of knowledge building in the community. Students contributed 70 additional resources (articles, videos, and reports) and used resources other students had shared in Yammer, referring to them in class or using them for their projects.

Findings indicate that the quality of posts were relatively high. Fifty-eight percent of the posts were classified as synthesis or interpretation of course content (see Table 6). However, there was a range of quality within each level. There were better and worse examples of rationale, evidence, and weighing of concepts in posts. For example, a student posted a video about the start of the wireless industry as a means to highlight how difficult it is to be an entrepreneur. Another student responded to this post by stating: "This is an interesting story. It shows that all beginning ideas will have their fair share of issues, no matter who is working on them. It also shows the perseverance and persistence of Steve Jobs and his company. Apple and the iPhone today are extremely successful, so consistent hard work does pay off." In this example, the responding student shared his opinion, supported that opinion with a rationale, and interpreted the main points of the story. For this reason, it was coded as a level 5, but it was one of the least sophisticated examples of interpretation because all of the claims were opinion-based and not supported by rationale.

The following example shows higher quality of interpretation than the previous example. At this point in the course, students were working on their group design projects and focusing on developing requirements documentation and initial design ideas. One student posted a resource for his classmates and stated the following:

> During the semester we were introduced to scenarios in design and how they can be used for expressing proposed or imagined situations to help in conceptual design. But not only can scenarios be used in the conceptual aspect, it can be used in prototyping as well. Scenarios can be used as a way to sell ideas to users and potential customers. There is a notion that there are plus and minus scenarios, which basically means that these scenarios try to determine/identify the most positive and negative consequences of a particular design solution. The purpose of said plus and minus scenario will help designers to gain a more comprehensive view of the proposed idea. Here is a PDF document explaining in further detail scenarios and its role in prototyping and how it interrelates to gathering requirements.

In this post, the student reminded students of a previous course concept relevant to their current work, design scenarios. He claimed that scenarios can be used to inform a

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designer's thinking in more ways than those highlighted by the course and explained his rationale. He then supported his assertions with a PDF document, thereby supporting his claims with evidence, extending classroom resources, and providing new tools that his classmates could use for their own projects.

Evaluation of argumentation practices

We conducted an in-depth analysis of argumentation practices and found posting behavior to be generally socially positive, and demonstrating deep thinking about topics, but primarily from a personal, anecdotal perspective. The posts in this environment adhered to the professional and respectful posting behaviors outlined in the moderation guides: 95.9% demonstrated *civil discourse* and none made personal attacks on other students. However, critical, fact-based evaluation of claims/ideas was low; 13.4% included an *alternative claim or idea*; 17.5% posts had evidence of *analysis of claims/ideas*; 2.1% included *use of fact-based evidence*.

Examining students' quality of posts when the instructor faded from the environment

Evidence from online discussion content indicates that posting quality increased rather than decreased, as the instructor became less central to the discussions. Table 7 shows the distribution of posts that correspond to each cognitive level across three time-points, with level 5 posts (highest cognitive level) to level 0 posts (lowest cognitive level) from left to right. Metacognitive posts are in the last column. The cognitive level of posts increases from T1 to T3, as level 5 and 4 posts increased, while non-content related posts, level 0 posts, decreased.

Discussion

Our findings suggest using the SCAD model can help instructors use discussion-based social network technology to develop an online community of learners. Table 8 maps our research questions to each factor we investigated and compares the expected outcomes from Table 1 with our actual findings. The table show that many of the expected outcomes were achieved.

When examining our first research question, we found that students took more central roles and increased levels of responsibility for the Yammer environment over time. For example, distribution of labor over the community was achieved. As the instructor's

Table 7 Percentage of posting type by time point

Time point	Cognitive level					
	5 (%)	4 (%)	3 (%)	2 (%)	1 (%)	0 (%)
T1	18.6	34.9	3.5	0.0	0.0	31.4
T2	43.1	27.8	1.4	2.8	12.5	2.8
T3	37.3	43.3	2.2	2.2	13.4	0.7

Posts are ordered from highest cognitive engagement, level 5, Interpretation, to lowest cognitive engagement, type 0, non-content related talk

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Table 8 A comparison of the expected outcomes from Table 1 to results of the study

Activity system nodes	Expectations met (Y, N)	Expected outcomes	Actual findings
Distribution of Labor (RQ 1.1)	Y	A shift in participation occurs over time: the instructor fades as the main contributor and multiple students take on the role of moderating and leading inquiry	Students took responsibility over the Yammer environment over time, leading inquiry threads and becoming more central as the instructor became more peripheral
Values (RQ 1.2 and 1.3)	Y	There is a variation in posting behavior: students read, reply, think about, and synthesize others' posts and create long threads of inquiry rather than question response pairings	There was an increase in variability of posting behavior over time and 25 long threads where students read, responded to, and synthesized other's original posts and responses to posts
Tools (RQ 2.1 and 2.2)	Y[a]	Most student led discourse is disciplinary in content: threads of inquiry are content-based, promote higher-order thinking processes, and show evidence of argumentation stemming from problematization of content.	Only 1.7% of student talk was off-task talk, 58% showed evidence of higher-order thinking, and 26.4% showed evidence of argumentation, but argumentation quality varied
Rules (RQ 2.3)	Y	Students maintained community values and promoted intellectual work even when instructor fades	Quality of student posts, as defined by level of cognitive activity, remained high even after instructor faded

[a]Expectations were mostly met, but argumentation quality needs additional support

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presence faded from the online environment, moving from the most central to peripheral participant, the role of central information giver and receiver became distributed among different students. This contrasts with the hypothetical scenario where the instructor's central position was simply substituted with a prominent student in an authoritative role. Instead of substitution, our findings show there were multiple students with high and medium centrality within the community over time. Structurally, this illustrates a transformation from a highly centralized form of leadership as commonly seen in classroom teaching, to a more distributed online community leadership that not only satisfies our sociocultural and pedagogical aims, but also reflects the characteristics of more sustained online learning communities like those found in open source software communities (McDonald et al. 2014).

We also found patterns of posting behavior that suggest students did not simply "do school" and make socially disconnected posts or provide quick responses to fulfil the weekly requirement. SNA findings illustrating the direction of engagement (in-degree = receiving messages and out-degree centrality = sending messages) indicated that students engaged in meaningful conversations with others by replying to the original poster as well as to each other. Further analysis of these posts showed that students read entire threads, as evidenced by their inclusion of references to previous posts in a thread for either building on or arguing against other student posts.

When examining our second research question, we found that students used the Yammer tool to think about course content with others. We found evidence that students discussed disciplinary content in fairly sophisticated and meaningful ways. After the instructor's presence faded, students were able to maintain, and in some cases, increase the post quality.

Our findings also highlighted particular needs not currently met by the model or the tools we developed. Of particular concern is the quality of argumentation in the environment. Researchers who study students' argumentation practices are likely not surprised by our findings that argumentation quality was fairly low, as it is often lacking in face-to-face learning contexts as well (Duschl and Osborne 2002; Noroozi et al. 2013; Weinberger et al. 2007). Nonetheless, this is an important issue to address in online contexts as more people turn to social media for information and engage in conversations with others to make sense of information.

There are many problems associated with the use of public discussion-based social media like Facebook for sharing and learning information. As Kirschner (2015) points out, there are many features within the system and practices that users have learned that can make productive argumentation "in the wild" unlikely. Del Vicario et al. (2016) show how these features can lead to the development of echo chambers and point out how higher participation within these groups can lead to more negative consequences.

Our students are immersed in social media platforms of multiple kinds and may therefore be internalizing negative social media practices. Without guidance, young learners may develop dysfunctional posting behaviors into adulthood when they may engage in more civic and political discussions or be manipulated by it. As such, learning how to use social media technology in productive ways, and understanding how participatory behaviors can impact a community is a critical type of digital literacy that students need to develop. Our model provides guidance and specific indicators that would emerge from analysis of content and log data. These indicators provide instructors with concrete guidance to apply in their own classes as a means to both create a community of learners and help improve the digital literacy of their students.

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Collectively, our findings provide evidence that high quality discussions can occur in an online learning community, while shifting the role of the instructor from leader to facilitator. Our SCAD model illustrates how to accomplish instructor role shifts in online communities in a systematic way, enabling more widespread exploration and learning in online learning environments. For researchers, it paves the way for exploring whether such theoretically informed approaches might scale to larger online learning environments. Instrumental to scalability are the collection of social structural and learning indicators for monitoring student progress and the evolution of the decentralized leadership model that our study implements. Together, these instruments support the monitoring and evaluation of future studies, enabling instructors to make adjustments to address nuances in specific classes, and researchers to have insight into the emergent family of adjustment categories teachers employ.

Guidelines for socio-cultural activity design implementation

Teachers and students play a central role in successful implementation of the SCAD model. They need to understand the desired outcomes of tool use and see benefit in putting forth the effort necessary to achieve them. As discussed, their experiences with other similar technologies can bias them against discussion-based social networking tools. Prior experiences can conflate the form and function of desired participation behaviors with those in other dysfunctional or more traditional online contexts. Learning how to use tool features is not enough. Students have to understand how to use discussion-based social network technology to interact with others in a productive and socially responsible way that supports learning.

Our study focused on articulating concrete steps necessary for integrating a discussion-based social media technology into a learning context for the purpose of developing a learning community. One limitation in our study is that the primary instructor had a deep understanding of sociocultural learning theory and could apply it to practice. However, many instructors may not have such knowledge. Thus, scaling this approach will require that instructors learn some aspects of socio-cultural theory upfront and how to examine concrete behaviors to evaluate the effectiveness of their own implementations.

The first author has used authentic practice as a means to help student teachers and graduate researchers to better implement the SCAD model. During this practice, the model was implemented as part of a course on computer supported collaborative learning for the purpose of getting student teachers and doctoral students to internalize core practices. In doing so, distinctions between an online course community and social media practices were seen and discussed, and student teachers learned to use the model as part of real authentic activity. Drawing upon these experiences, we suggest supporting the following activities during teacher preparation:

- *Support systems thinking* Introduce student teachers to the basic concepts of an activity system by focusing on a classroom system, a system they understand. Provide concrete examples of how classroom-based factors within a classroom system interact with each other. Provide clear examples of how interactions between tools, distribution of labor, rules, and values can impact the development of a learning community.
- *Support expert modeling* As part of the authentic practice experience, it is important to review the core pedagogical components by having the expert instructor articulate their thinking as they engage in different online posting practices. This way, student teachers

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can develop their understanding of specific moderating practices necessary to achieve desired results.

- *Support ongoing reflection* Allow student teachers to take part in assessing participation and the quality of posts at regular time intervals during the course. In this way, the community can practice their ability to make necessary changes to the system.
- *Support articulation of thinking* Push student teachers to articulate what the structural evolution of engagement looks like in the system as it evolves from teacher centered at the beginning to student centered in the middle and end (with a growing rate of student centeredness). Push student teachers to explain how the discourse is evolving and why desired changes are important.

These types of professional development activities can provide student teachers with a deeper understanding of the SCAD model and prepare them to use discussion-based social media technology as a rich dialogical learning tool. Graduate student researchers can pair this learning with basic social network analysis (SNA) training so that they can conduct analysis of their own, but student teachers do not need to learn SNA to be able to carry out the model.

Limitations of the study

While our findings are promising, there are limitations arising from the nature of the research conducted. The main limitations of this research were the size of our population and a lack of access to other classes that could serve as controlled comparisons. While these types of limitations are standard for design-based work, future research could address these limitations. Multiple teachers could be trained to implement the SCAD model using the guidelines we provided, which would provide opportunities for larger studies that examine the utility of the model and how the use of different support tools can impact outcomes. Future studies should also include student perceptions of the utility of the model and include a fine-grained analysis of the strengths and weaknesses of our pedagogical approach. This line of work could lead to a better understanding of the variables associated with rich discourse environments, so as to better meet the needs of students and online communities.

Conclusion

Too often, technologies are introduced without explicit sociocultural guidance or alignment between desired outcomes and outcomes that the technology itself may unknowingly promote. The lack of systematic support leads students to develop online behaviors in the wild. Therefore, it is not surprising that there are so many inconsistent findings when it comes to the use of technology for learning or for building community. This is true in educational settings and everyday settings like Facebook and Twitter that have recently led to the polarization of political discourse and the manipulation of users through fake news (Allcott and Gentzkow 2017; Lazer et al. 2018; Sunstein 2018).

Social media platforms can be conceptualized as virtual spaces for learning in their own right, as spaces for learning through discourse and persuasion. Our findings show that, when properly supported, these virtual spaces can lead to productive disciplinary engagement, where participants take on responsibility for their own learning as part of a learning

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community. These types of educational experiences could help students to become more conscientious online citizens and create productive, civil discourse desired from social media (Agre 1995, 2004). With growing awareness of the power of discussion-based social media tools in everyday life, more research is needed on how people learn in these spaces and how to design instructional models to support positive socio-cultural activity within them.

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