ORIGINAL RESEARCH

Social Network Analysis as a Cybernetic Modelling Facility for Participatory Design in Technology-Supported College Curricula

Shantanu Tilak[1] · Marvin Evans[1] · Ziye Wen[1] · Michael Glassman[1]

Abstract

Despite iterative learning design being increasingly implemented, such approaches are often delineated by well-defined periods of design/implementation. However, second-order cybernetics, which suggests a participatory approach to learning design, involves responsively adapting learning environments to meet students' needs, treating them as agentic participants in the classroom. In our mixed methods study, we investigate whether such a process can facilitate egalitarian participation and collaborative interactions in a technology-assisted classroom. We use the example of a graduate psychology class of 17 students and suggest that adaptation of live-chat activities by a participant observer on the Reddit social media platform that supplemented the in-person lecture dynamically, using a network analysis and qualitative ethnography as a modelling facility mimicked the ongoing feedback loops of social media platforms, enabling students to use social media with a critical eye, and engage in productive collaboration. Our quantitative results present network graphs for weekly eigen centrality to understand the egalitarian nature of the network, and transitivity to understand the likelihood for collaboration between more than two agents. Our qualitative results elaborate selected Reddit posts, and weekly field notes to explain how redesigning the chat weekly helped augment lecture-based discussion with the instructor and critique of student presentations, spurring egalitarian participation through a space-place dialectic. Students also provided end-semester feedback that was analyzed using inductive coding, to design future courseware.

Keywords Network science · Participatory action · Cybernetics · Curriculum design

Introduction

Social theorists like Paulo Freire asserted that a banking model of education, that involves using prescribed packets of knowledge to educate students, could stifle the capacity for reflection, or the consideration of varied standpoints to produce nuanced solutions during

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problem-solving. Freire (1982) believed that adult education could produce higher-order thinking only if researchers were able to actively participate in understanding the evolving cultural experiences of students dynamically, to create educational experiences that find application to solving real-life problems. Other scholars such as Vio Grossi (1982) agreed with Freire's participatory action approach, suggesting that researchers/designers of educational experiences should act as participant observers in educational environments, to become familiar with the targeted experiences of learners and design curricula enabling them to become agentic perspective takers in the classroom.

With the Internet becoming a publicly available tool in the late 1990s (Boyd and Ellison 2007; Tilak and Glassman 2020), and the rapid expansion of corporatized new media technologies (Chavalarias 2016), tools such as social media produce cybernetic feedback loops that constantly influence human thinking and action on an ongoing basis, creating explore feeds and content that tries to reverse engineer preferences to drive revenue. Cybernetics is a transdiscipline that enables an understanding of how complex systems (brains, individuals, societies and even machines) adapt and react to moving social fields to exercise goal-oriented behavior (Flood and Carson 1993; Tilak et al. 2022a). When applied to the use of online technologies, cybernetics may expose the cognitive/social mechanisms and design parameters to create goal-oriented learning environments (Pangaro 2008) that foster nuanced reflection and perspective taking through the use of tools like social media (Tilak and Glassman 2022). The cybernetic capacities of Internet tools add another layer of ongoing human experience that educators must consider in designing technology-supported curricula to account for the everyday experiences of students. In such a context, individuals embedded within highly interconnected societies must attempt to understand how their actions and behaviors on the Internet affect larger sociocultural systems. The constant interplay between the chaos of the world and the attempts that humans make to create some meaning out of it is the crux of cybernetics; such ideas have even found expression in European literature. Italo Calvino's Mr. Palomar, which acknowledges the role of cybernetic framings in explaining human adaptation and development, is a prime example of reflexive thinking about the ramifications of one's actions. Calvino writes about the constantly changing reference frames that Mr. Palomar takes of the world, in the chapter "The Infinite Lawn," describing how the protagonist's mind wanders from a menial gardening task to musings about the universe:

> Mr. Palomar's wind has wandered; he has stopped pulling up weeds. He no longer thinks of the lawn: he thinks of the universe. He is trying to apply to the universe everything he has through about the lawn. The universe, perhaps finite but countless, unstable within its borders, which discloses other universes within itself. The universe, collection of celestial bodies, nebulas, fine dust, force fields, intersections of fields, collections of collections. (Calvino 1983, p.33).

The Internet has produced increased capacity for networked interaction (e.g., grassroots organization of #BlackLivesMatter protests through the use of Twitter; Thelwall and Thelwall 2021) but also several concerns (e.g., conspiracy theories on Telegram; Walther and McCoy 2021, & heated, polarized debates about issues such as vaccinations and climate change; Barzilai and Chinn 2020), requiring humans to critique and view the world through varied standpoints, much like Mr. Palomar. The concerns associated with the use of social media have led to the consensus that algorithms must be redesigned to loosen control on consumer behavior (Bayles 2022; Carr 2021); and that the social capital accrued on such platforms needs to be separated from the classroom (Haythornthwaite et al. 2018; Stahl and Hakkarainen 2020). However, tool build and user agency interact to produce

these concerning eventualities (Glassman 2016); the design features of technologies and the nature of human agency may both be engineered to produce adaptive social exploration and collaboration. In such a context, equipping learners with a critical eye for activities such as information search and productive online collaboration may allow them to exercise critical thinking and understand the ramifications of their actions in navigating the ongoing cybernetic feedback loops of the Internet in their everyday lives. Educational spaces become safe, norm-driven environments to steer human behavior in an information-saturated society (Barzilai and Chinn 2020) through the use of social media technologies towards critical thinking, to tame the wicked problem of online polarization.

Our mixed methods study suggests a way to help students navigate the cybernetic feedback loops of social media with a critical eye by mimicking their ongoing effects on human agency through a cybernetic interaction design approach emblematic of participatory action research. We outline our comprehensive design case involving adaptation of social media driven activities on the Reddit platform in a graduate psychology classroom on an ongoing basis, fueled by insights obtained from a network analysis of weekly student interactions. We also highlight how these ongoing design processes augmented class-based discussions through an elaboration of lecture-based interaction and student presentations using ethnographic field notes.

The theoretical framework guiding this study is divided into three parts. We first describe the applications of cybernetics to curriculum creation and highlight how this study derives the notion of participant observation and the use of a modelling facility to parametrize classroom data to inform iterative design insights from psychologist and cybernetician Gordon Pask's (1975) conversation theory. We then understand how current studies applying network analysis in isolation and in concert with other mixed methodologies (Ouyang 2021), and co-design processes to investigating collaboration in educational environments (Byrne and Tangney 2010; Lui and Slotta 2014) usually rely on a first-order cybernetic approach, involving the application of curricular tools designed in an *a priori* manner, or demarcated by well-defined periods of data collection and analysis rather than a radical participatory design approach that enables a constant retooling of technology-assisted educational environments based on the emergent needs of learners. Finally, we display how the present design study applies network analysis within the framework of second-order cybernetics, accompanied by qualitative approaches, taking inspiration in part from a seminal study in network science (Rand et al. 2011) that focuses on the dynamic adaptation of human interaction to heighten collaboration and reflection.

Theoretical Framework

Cybernetics and Curriculum-Design

Usually, technology assisted learning environments are crafted by course designers keeping certain affordances or features in mind, that are projected to produce certain learning outcomes and changes in thinking and behavior in the classroom. The course designer often works in a detached manner with the system, only making changes once implementation has concluded, to adapt affordances of the environment to heighten collaboration, exploration and information seeking. The feedback loop returning insights from the observed classroom system to the designer is weakened, and only considered much after implementation. Scott (2014) suggests that such an approach lies within a first-order cybernetic

framework. This would constitute treating the classroom system as a relatively static set of variables investigated by the observer, rather than meeting the emergent needs of learners within the system, who constantly change their reference frames of provided content, and of their social worlds. As we have explained in the introduction to this paper, the added layer of Internet experiences turns students into active agents (Glassman 2016) embedded in an information-saturated reality (Barzilai and Chinn 2020), requiring educators to equip them with social capital they can use to navigate polarized online environments.

Since the feedback loops of the Internet are an emergent, ongoing phenomenon that may change behavior and thinking in unpredictable ways (Chavalarias 2016), we suggest equipping them with the skills to use such technologies in norm-driven environments like classrooms may require a dynamic design process emblematic of participatory action research that mimics the emergent nature of these feedback loops (Tilak and Glassman 2022). An emergent approach to crafting technology-assisted activities in classrooms adopts the principles of both participatory action research (Freire 1982), and the reflexivity of second-order cybernetics (Pask 1975), with the course designer becoming a participant observer who adapts the technology-assisted environment by treating students as a collective who change their reference frames of the world, and of educational content.

The seed or origin point for the reflexive turn in cybernetics was planted when anthropologists such as Margaret Mead and Gregory Bateson brought their work in Balinese and Aztec communities to the Macy conferences on cybernetics, helping mathematicians and engineers in attendance understand how complex living systems transformed their standpoints and constructed new forms of cultural knowledge in an open-ended fashion (Pias 2016). The Electrical Engineer and epistemologist Heinz von Foerster (1974) later coined the term "second-order cybernetics" suggesting that this branch of cybernetics could be used to investigate cognitive and sociocultural phenomena in dynamic social fields (Tilak et al. 2022a, b), strengthening the feedback loop from the observed system to the observer and understanding how ongoing modifications can be made to stabilize the system.

Von Foerster applied the ideas of second-order cybernetics to curriculum construction at the University of Illinois, Urbana-Champaign, creating a cross-disciplinary heuristics course offered the students of the department of Electrical Engineering and English Literature. The class was project-based and involved several guest speakers explaining concepts related to the brain's adaptation in a cross disciplinary manner, and the ongoing collective creation of scholarly papers, free verse poetry, and graphic art based on the emergent insights of students (Dubberly and Pangaro 2015; Tilak et al. 2022a) that culminated in the text, *Cybernetics of Cybernetics* (von Foerster 1974). The course was based on educational psychologist and cybernetician Gordon Pask's first theorem, which states:

> If a system is legitimately said to teach, then it must be able to learn from its student who may reverse the roles to play at teacher (Pask 1972; p.243).

Pask designed tools such as the Course Assembly and Tutorial Environment (CASTE) that could allow learners/users to iteratively explore curricula and contained modelling facilities to record and measure student learning/uncertainty about topics on an ongoing basis (Wilson and Scott 2017). Thus, the student could provide the device with insights that the course designer could use to adapt the curriculum to better meet their needs, and even learn from the device by providing explanations and demonstrations. In Pask's framework, learning became an iterative, cyclical conversation between machines, learners, and course designers. Conversation theory, or the genesis of Pask's cybernetic approach to creating technology-assisted learning aimed to expose the cognitive mechanisms of using computers/tools and enable designing such environments to spur concept development

(Pangaro 2008; Tilak and Glassman 2022). We rely on this idea and use a social media platform, Reddit, as an output mechanism to reveal the cognitive mechanisms of collaboration in the classroom and analyze this data using social network analysis as a modelling facility to parametrize interactions on a weekly basis and suggest ongoing design changes to the social media driven activity. We suggest that redesigning the activities on Reddit in an iterative fashion to better meet the needs of students enabled greater reflectivity in lectures and during student presentations. Our study advances participatory approaches to technology-assisted curriculum design and the applications of network science to analyzing collaboration and interaction in educational settings by looking back to Pask's often forgotten cybernetic approach. In the next section, we recount current literature in these specific fields of inquiry and outline how our cybernetic approach shows potential to create a radical, dynamic shift towards participatory action research in curriculum design.

Current Approaches to Designing Technology-Assisted Collaborative Environments

As we have outlined, the idea of setting out affordances for a technology-assisted educational environment (Jeong and Hmelo-Silver 2016; Kirschner et al. 2004) and expecting outcomes to emerge within the constrained boundaries of a theory of change lies within a first-order cybernetic framework to curriculum design. There have been attempts to try to expand such first-order approaches to involve ongoing partnerships between designers/observers, students, and practitioners (Spikol 2011), wherein observers act iteratively to alter the structure of curricula based on the emergent needs of students and practitioners (Fig. 1).

Fig. 1 Interaction design
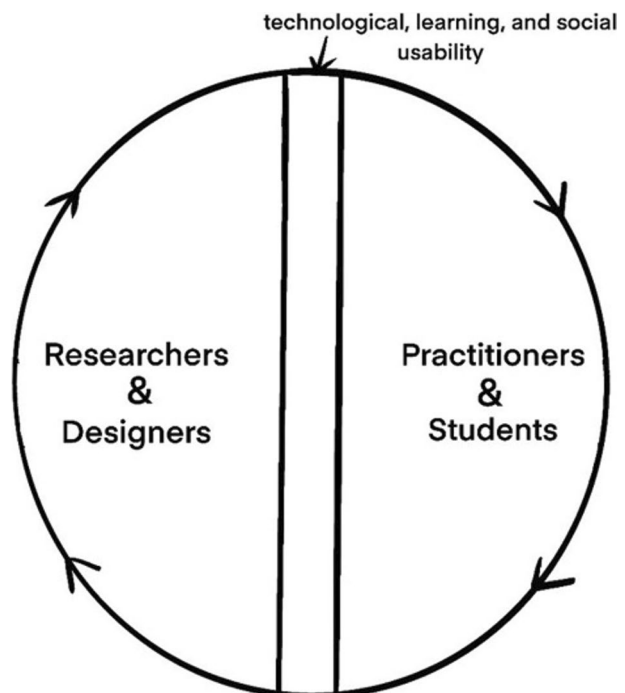
The idea of iterative design (or as cyberneticians would term it, interaction design; Pangaro 2008) has been applied to designing curricula across several age groups and domains at varying levels of intensity. For example, Lui and Slotta (2014) co-designed an immersive simulation-based environment with high school biology teachers and students to spur collaborative learning about the evolution of rainforests. Tilak et al. (2022a, b) worked with high-school social studies teachers and elementary schoolers to design curricula employing multimodal tools for social perspective taking and collaboration, focused on issues such as food security (economics) and Native American history. The authors conducted focus groups with students between each curricular iteration and updated the design features of the technological toolkit after each round of implementation.

Glassman et al. (2013) applied the idea of participatory design to craft curricula based on the use of discussion boards in an undergraduate psychology classroom. The authors analyzed the blog data and observed the organic progression of the online community to understand how to design the second iteration of the class. Initially, the blogging community was run based on instructor-provided prompts, which led to students' perception that they would have to do the bare minimum to be considered agentic participants in the blogging activity. But, in the second iteration, the authors decided to change the structure of the blogging activity to highlight and showcase compelling student posts based on the frequency of responses and reactions and relate them to the weekly topics covered in class. This design process enabled students to feel like they had a voice in the classroom. Evans et al. (under review) and Miller et al. (under review) have expanded this participatory approach to designing collaborative technology assisted classrooms employing social media platforms such as Reddit, which have been shown to encourage discussions that weigh out varied perspectives about topics such as gaming (Haythornthwaite et al. 2018) and COVID-19 (Lai et al. 2020; Tilak et al. 2021). These approaches aim to incorporate the social capital accrued in informal Internet environments into the classroom but have used design approaches demarcated by well-defined periods of curriculum implementation and data analysis. However, they do suggest that the governing variables and design processes used to create Internet-assisted learning environments cannot be rehashed from existing *a priori* approaches to curriculum design in formal environments (O'Reilly 2007). Emergent design may mimic the feedback loops of Internet platforms, helping designers and instructors design goal-oriented environments that equip learners with social capital that they may apply in navigating complex social realities.

Social network analysis is a methodology that provides scope to measure and understand the collaborative processes between students through the use of technology (Ouyang 2021), and can act as a modelling facility to understand how to restructure activities on an ongoing basis based on parametrized metrics assigned to the nature of distributed interaction. Presently, social network analysis has been applied using three approaches to analyzing interactions in educational environments, namely, to measure the nature of node-level interactions between students (Ouyang et al. 2020; Saqr et al. 2020), to measure the interactions of students embedded within certain topics (Cela et al. 2015; Dado and Bodemer 2017), and to understand how interactions display socio-cognitive mechanisms and discuss complex concepts, employing quantitative models and content analysis in concert with network analysis (Shaffer et al. 2016; Wise and Cui 2018). This means that it becomes possible to map the quality and quantity of student interactions using network visualizations and graph theory. Metrics such as transitivity (which explains the frequency of closed interactions between two or more people), and eigenvector centrality (which understands how frequently users in a network interacted with popular agents in the system) can provide an understanding of how cohesive interactions within an online educational community

are (Kolaczyk and Csárdi 2014). When the likelihood for transitive interactions increases, transitivity approaches 1. Since eigen centrality measures whether connectedness is distributed across nodes, its value depends on the magnitude of the initial eigenvalues of nodes in the network (Iacobucci et al. 2017). In this study, we use network analysis and narrative inquiry design (Connelly and Clandinin 1990), to tell a weekly story of classroom interactions and how they informed a weekly redesign of social media driven activities.

Despite the potential to apply network analysis to participatory design, this method has largely been used within a first-order cybernetic framework to aid in curriculum design (see Ouyang 2021 for a review of studies and methodological frames), to analyze data from educational interventions and curricular design cases after implementation. In this study, we use network analysis as a modelling facility, to analyze the output from student interactions on a social media platform on iterative basis to gain insights to redesign the online activity, thus blurring together processes of curriculum implementation and data analysis into a continuum that adopts the tenets of Gordon Pask's cybernetics and participatory design. We also suggest that such participatory design for the technology-assisted activities in the classroom mediated by social network analysis may produces higher collaborative discourse and ideological back and forth in lectures and student presentations, producing what is known as a space-place dialectic (Glassman and Burbidge 2014). In the next section, we explain how ideas related to cooperation in fluid networks inform the methods used in this paper.

Cooperation & Fluid Networks: Applying Network Science to the Present Study

As we have outlined, network analysis may help understand how collaboration may spur social contagion and concept development in a sociotechnical environment (Kolaczyk and Csárdi 2014). Using this method can explain how cooperation drives humans to engage in distributed behaviors that may change ideologies about certain topics and phenomena. Most network studies suggest spread of social contagion occurs through shared experiences in networks about topics of joint interest (Palla et al. 2007; Fowler and Christakis 2008) and arising from collective experience in one's home, or neighborhood (Nickerson 2008). However, behavior also emerges in response to structure of the environment; adapting ties through restructuring collaborative spaces/fields may help amplify collaboration by amplifying the variety of perspectives interlocutors are exposed to and encouraging them to engage in discourse to weigh out these perspectives, effectively engaging in critical reflection. This idea may also apply to decoding whether online settings offer optimal environments for collaboration, since they allow for both information uptake and distributed conversation. However, on social media (posting to a timeline), and in online educational communities (exchanging ideas on class discussion forums), where gaining information is often prioritized over reflectivity, the chance for trivial interactions without much scope for reflection is immense (Tilak and Glassman 2020). Altering these spaces dynamically, to meet the needs of users may heighten collaboration. Network analysis, which has often been used in cybernetics to understand the structure of information flow in organizations (Mayer 2012), may offer insights into the mechanisms through which dynamically altering cooperation in social and educational settings may spur knowledge co-construction.

Rand et al. (2011) used network analysis as a modelling facility to understand how providing greater flexibility to make and break ties in an economic game stabilized cooperation with time. 785 participants played a game wherein cooperation involved paying 50 monetary units to a partner, with each collaborator gaining 100 units. Defection produced

no reward. Three conditions were tested. The first was the random link condition, wherein network ties were changed randomly. The second was the static condition, wherein the network configuration remained constant throughout. The third strategic link updating condition allowed users to strategically update ties at different frequencies, divided into two facets; a fluid-dynamic network with greater frequency of self-selected shuffling, and a fluid-viscous network, where shuffling frequency was lower. Greater autonomy for reorganization produced cohesive collaboration. Such autonomy is deemed by cyberneticians specializing in social science as the fuel for the development of novel conceptual knowledge and higher-order thinking aiding in navigating social realities (Pask 1975; Scott 2021).

In this paper, we hypothesize dynamically altering an online discussion in an educational setting provides greater opportunities to produce egalitarian cooperation. We use social network analysis as a mechanism to provide insights for changes in the configuration of the online live-chat in a technology-supported classroom, operationalizing it as a pathway to guide instructional design, rather than solely as a mechanism for evaluation after learning has occurred.

The Current Study

In this mixed methods study, we investigate whether dynamically altering the structure of online live-chats using social network analysis as a weekly feedback mechanism may create a cohesive online learning community in a graduate-level classroom, and create an ethnography from lecture field notes, to explain how online discussions were linked to concept development and distributed conversations in class lectures and student presentations (a place-space dialectic; Glassman and Burbidge 2014). We also employ inductive (Bingham and Witkowsky 2021) qualitative analysis to understand students' end-semester feedback and propose using insights to inform future courseware design. We posit three hypotheses suggesting using network analysis for participatory design may:

H1: Help stabilize transitivity of discussions with time, or tendency for formation of closed ties between more than two individuals.
H2: Increase egalitarian network participation.
H3: Increase connectedness of members in the network to influential others.

We ask one exploratory research question to understand establishment of the place-space dialectic:

ERQ1: Can an evolving online discussion designed iteratively to build community interactions forge stronger links between online activity and conversations in place-based lectures?

Materials and Methods

Data

Data were drawn from three sources. The first were online chats on Reddit set up for graduate students in a 14-week seminar part of the education department at a large, Midwestern research university, conducted during the first 15-minutes of each session. Network analysis was conducted on the weekly chats. The second source were the fieldnotes the researcher took of conversations occurring during lectures and student presentations that followed online live-chats, to employ ethnography in explaining the link between richer online interaction and face-to-face discourse, and supplement weekly design decisions for the online chat. The third source was an end-semester feedback chat.

Participants

All 17 graduate students consented to participating. 16 provided demographic details (owing to one absence). 62.5% students were female. 62.5% were White, 12.5% were Black/African American, 6.25% were Asian, and 12.5% were Multiracial. Ten (most of the class) belonged to the School Psychology major, which focuses on counselling practices in schools. One belonged to social work, one to the music department, one to science education, one to educational philosophy, one to the school of public policy, and one to the educational psychology major. The course was Educational Psychology: Social Basis of Behavior, focusing on theories portending behavior and mental models are constructed by complex environments we inhabit.

Curriculum

The curriculum created by the instructor comprised weekly readings about approaches to understanding development of thinking as a social process guided by an integrated process of action and cognition. Each lecture began with a 15-minute in-class lightning-chat on Reddit wherein students responded to a weekly prompt, expanding ideas being discussed. Reddit was chosen owing to its capacity to create a private community to discuss targeted topics. and its live-chat functionality allowing threaded discussions to be visible as they progressed. We wanted anonymity in live discussions owing to the sensitive nature of school-related issues and considering a sizable proportion of the class were School Psychologists, who often feel their opinions need to be expressed in safe spaces. Students sat at their computers in class as discussion prompt(s), presented either as live-chats or blogs, appeared on a shared-screen (for online sessions in the first three weeks), or on the classroom projector (for subsequent in-person sessions).

After discussing the prompt, the class moved into a lecture covering weekly readings, involving open-ended idea sharing between professor and students. For the first seven weeks, lectures were longer, lasting two hours. Students watched and responded to videos and media about weekly topics, in addition to discussing weekly readings. Starting Week 8, the last 40–45 min of class involved student presentations (conducted in groups of 2–3 students) corresponding to weekly topics. After each presentation, students commented on a peer review blog on Reddit to share what they learnt from colleagues' presentations. Live-chat participation, and posting peer-review was voluntary but encouraged, and the live-chat component was continuously remodeled based on weekly behaviors. Grading was

conducted based on presentations, and retrospective reaction papers responding to classroom discussions and readings for any two sessions. While live-chats were ungraded, they were linked to classroom content, reaction papers, and presentations, making participation a source of deeper understanding of class content. Weekly topics, and in-person/online format of teaching for each class are provided below (Table 1). The last session was a feedback session, wherein students reported perceptions of mechanisms of learning using Reddit, its strengths, and weaknesses. A short lecture followed, focusing on the role of the Internet in education, relating strongly to the feedback questions.

Data Analysis

In our study, the researcher acts as a participant observer, understanding how the classroom system evolves in real-time. The observer set up the live-chat each week and watched lectures and student presentations throughout the semester. RStudio was used to conduct network analysis on live-chats after each lecture. Metrics for individual and average degree (or connections each individual had with others), in and out-degree (incoming and outgoing interactions), transitivity (likelihood for closed ties between more than two individuals), and eigenvector centrality (likelihood for an individual to be connected to influential others) were computed (Kolaczyk and Csárdi 2014). These were used to understand weekly online interactions as they help explain the nature of distributed interactions between a small set of agents, and whether adapting the network produced a cohesive online learning community.

The participant observer also took fieldnotes derived from conversations linking concepts in live-chats to those in the lectures, and student presentations, and discussed these with the instructor and research team. These fieldnotes helped the research team to construct an ethnography (Angrosino and Rosenberg 2011) to understand whether live-chat ideation spurred reflection and argumentation in the face-to-face lecture, and deeper discussions of student presentations (establishment of a space-place dialectic through online learning). The frame of reference of the observer is provided in Fig. 2.

Table 1 Weekly topics and class formats

Session	Topic	Class format
Week 1	Reddit demo, curriculum overview.	Online
Week 2	Performance vs. Mastery learning	Online
Week 3	Social contexts and schooling.	Online
Week 4	Socioemotional learning.	In Person
Week 5	Constructivism and direct instruction.	In Person
Week 6	Socio-developmental factors in learning.	In Person
Week 7	Modes of instruction.	In Person
Week 8	Cognitive, constructive mechanisms in learning.	In Person
Week 9	Teacher training in collaborative curricula.	In Person
Week 10	Cultural/social capital in learning.	In Person
Week 11	Radical education and banking models.	In Person
Week 12	Motivation and interest in learning.	In Person
Week 13	Diversity in education.	In Person
Week 14	Feedback, discussion about role of the Internet in learning.	In Person
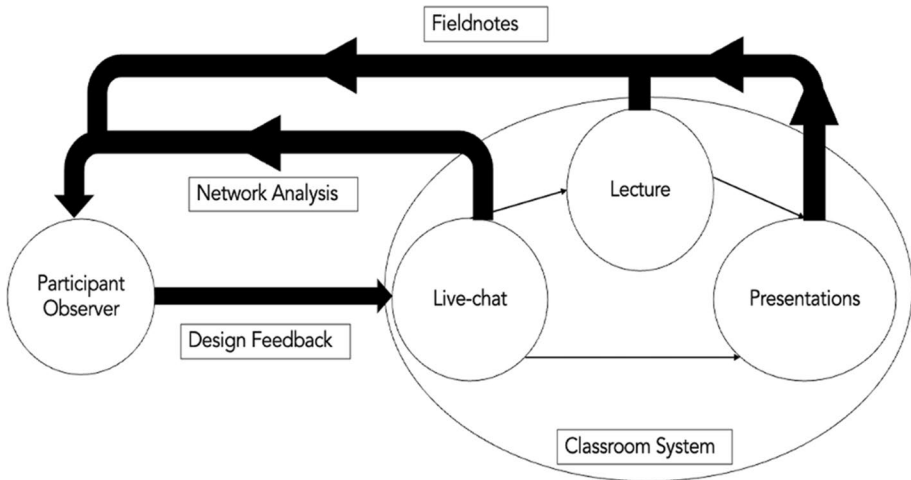
Fig. 2 Frame of reference

Responses in end-semester feedback were collected in Week 14. Two researchers inductively coded feedback to understand how insights could be used to redesign further courseware.

Design Phases for Lightning Chats

Seven design phases emerged. The first involved a Reddit demo, and instructions to make an account. The next two weeks, constituting Phase 2, involved picking the modality for semester-long discussions (choosing between live-chats and asynchronous blogging). Phase 3 involved developing comfort with live-chatting by reducing instructor contribution, to gradually model independent peer-peer conversations. Upon seeing a critical mass in Week 6 with a smaller group, we subdivided the discussion into two randomly assigned groups in Phase 4, constituting Weeks 7, 8, and 9. Hearing students complain about the lack of instructor support in helping understand the prompts, Phase 5 involved instructor modeling through in-person commentary as live-chats progressed. Seeing more egalitarian participation, we granted students autonomy to self-select prompts in Phase 6, spanning Weeks 12 and 13. Phase 7, constituting Week 14, involved a feedback chat about the class. The seven design phases are described in Table 2.

Our results comprise sociograms for weekly chats, narrate weekly occurrences from the face-to-face lecture, and explain how the online network was adapted in subsequent sessions based on weekly insights, and whether such reformulation produced an egalitarian learning community that was able to engage in productive collaboration online, and face-to-face. We also analyze student feedback to inform further course design iterations.

Table 2 Seven design phases

Phase	Format of Reddit discussion and timeline
Phase 1: Demonstration	Week 1: Reddit demonstration.
Phase 2: Finding a modality	Week 2: Live-chat, one group, instructor and designer participate. Week 3: Asynchronous blog, one group, instructor and designer participate.
Phase 3: Fostering comfort	Week 4: Live-chat, one group, instructor and designer participate. Week 5: Live-chat, one group, instructor, and designer refrain from participation. Week 6: Live-chat, one group, instructor and designer refrain participating, critical mass seen.
Phase 4: (Over)diversifying the network	Week 7: Live-chat, two randomly assigned groups, instructor refrains participating. Week 8: Live-chat, two randomly assigned groups, instructor refrains participating. Week 9: Live-chat, two randomly assigned groups, instructor refrains participating.
Spring Break	
Phase 5: Modeling the chaos	Weeks 10 & 11: Live-chat, two randomly assigned groups, instructor models conversation through in-person support as students chat.
Phase 6: Providing (some) autonomy	Weeks 12 & 13: Live chat, two self-selected groups, instructor models conversation through in person support as students use the platform.
Phase 7: Feedback	Week 14: Live chat as a feedback session to gather insights about implementing next iteration.

Results

Our network diagrams are stratified by node size, color and edge thickness, with pink nodes indicating greater than average in degree, larger nodes indicating higher degree, and edge thickness indicating higher weight of interactions. The key is provided in Fig. 3. Each set of sociograms is accompanied by examples of comments from the online discussion, and a narrative inquiry into the following lecture based on researcher fieldnotes, to indicate whether richer online interactions produced deeper ideation in the face-to-face lecture, and during discussions of student presentations that began in
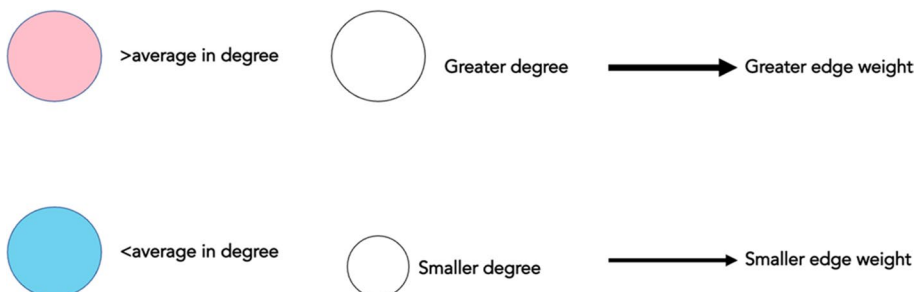
Fig. 3 Key for network diagrams

Week 8. For Phase 7, we conducted inductive qualitative analyses of student feedback to understand emergent themes in their responses, that could be used to redesign our future classroom curricula.

Phase 2

In Week 2's online class, we began live discussions in the first 15-minutes. The topic was the viability of grades. It being the first-time students had used Reddit for live-chatting, they were curious about its functionalities. 11 out of 16 students participated. The discussion produced insights about necessity of an evaluation system for account-ability, and simultaneous need for mastery and applied project-based understandings of content. Students avoided taking concrete stances, trying to understand how one could split the difference by navigating current testing-heavy paradigms, and inserting shared understanding and exploration into current approaches. An active user, SG, suggested:

> I think we should have grades to serve as a metric on how well students are doing. There is subjectivity to grades due to discretion of the teacher/professor, amount of effort put into the class, etc.

The instructor and two designers participated, challenging students, to help familiar-ize them with openly contributing to the platform. Fairly extensive interactions were seen, with 123 comments produced. Transitivity was 0.55, indicating a high incidence of closed ties. However, only instructor and one other user showed in-degree above average (Fig. 6), with total degree imbalanced across users. After the live-chat, some students reported the fast stream of ideas led them to feel distracted, perhaps leading the five missing participants to avoid posting. This led us to test the viability of asynchro-nous blogs for Week 3. The lecture after the live-chat focused on the Dewey-Thorndike debate (Levin 1991), and understandings of learning from a pragmatic and metricized perspective. Students raised arguments pertaining to merits and demerits of mastery and grades-driven models of education, remaining insistent on splitting the difference.

Week 3's online class discussed the role of social contexts in education, and the chat discussed the role of police in schools. Responding to students' concerns about the chat speed, and prioritizing them over network results showing high transitivity, we hosted an asynchronous blogging activity in the first 15-minutes so students would not be overwhelmed. Most discussants took one-sided stances indicating presence of legislative authorities could worsen school climate, with some suggesting crises could merit involvement of police. There was little back and forth, with average degree and in-degree dropping owing to the static blog. 13 of 16 students posted; but contributions were limited, reflecting tendency of students to post a trivial comment and response to conventional discussion boards before disengaging (Tilak and Glassman 2020). Stu-dents and instructor agreed live-chatting was the ideal format, despite concerns with speed. This decision was supported by a drop in transitivity (0.18), average degree, in-degree, and eigen centrality (0.38). The following lecture, about the role of policy and larger social systems in schooling, discussed using the example of Bronfenbrenner's (1979) bioecological model, was instructor-led, arising from lower engagement in the chat. Network diagrams and measures for Phase 2 are provided in Fig. 4; Table 3.

Having understood a live-chat was the ideal modality, the class and observer decided to implement a live discussion in one large group.
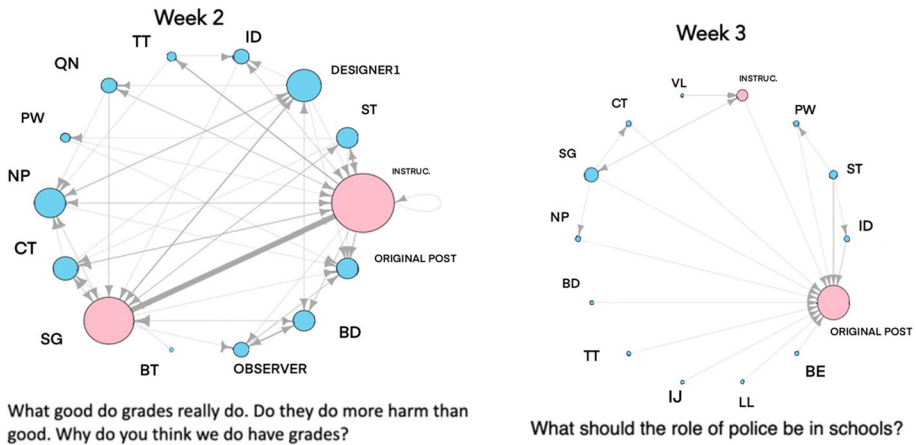
Fig. 4 Network diagrams, Phase 2

Table 3 Centrality measures, Phase 2	Degree	In	Out	Transitivity	Eigen centrality
Week 2	7.71	3.86	3.86	0.55	0.45
Week 3	2.71	1.35	1.35	0.18	0.38

Phase 3

In Weeks 4, 5 and 6, we tried to understand whether sustained interactions using the preferred live-chat modality would increase egalitarian cooperation. In Week 4, class began in-person, and the group discussed socio-emotional learning (SEL), or curricula designed to enhance self-management and emotional well-being. 14 of 17 participated. The live-chat featured arguments about monetization of SEL toolkits that have been recently popularized, and whether using prescribed toolkits, or organic collaborative processes for students in need would help improve school climate. User GB commented:

> SEL is not a magic bullet for struggling students. Some may take away life-long benefits and others may not take away anything. It is efficient for SEL to be delivered in small groups of at-risk students- to not interfere with instruction time for those who equipped to handle their emotions.

A high transitivity of 0.42 was seen, with average degree and in-degree showing increase, owing to use of live-chats in accordance with students' suggestions. Mean eigen centrality remained constant (0.38) indicating users were not more likely to be connected to influential others. The instructor and three other users showed in-degree greater than average. In the lecture, the instructor screened videos of common teacher techniques to instruct emotional management, spurring discussions about whether such skills should be fostered by providing information top-down, or whether SEL should be embedded into organic processes of collaboration. Responding to the video, students admitted they had not thought about SEL this way, and agreed presenting information from prescribed, evidence-based toolkits may serve financial and corporate interests rather than meeting the needs of students, expanding on their online conversation.

Students were asked to peer review the instructor's presentation after class on the asynchronous Reddit blog and were told that a voluntary peer review process would be conducted every time students presented.

Beginning Week 5, the instructor refrained from live-chat participation, wanting to see whether four weeks of chatting, and increasingly constructive face-to-face conversations that followed, allowed students to get more comfortable with using Reddit. The instructor exiting the chat initially caused shock, affecting collaboration, and lowering transitivity (0.34). The prompt was based on developmental factors, asking about merits and demerits of changing mandatory schooling ages. Despite the instructor's exit, all 17 students participated, and used concrete examples to support their ideas rather than relying on the previous modeling of the instructor to expand ideas. Most agreed lowering the age would allow early intervention. User CT, suggested:

> I agree with everyone about lowering age because of early intervention; this may narrow achievement gaps as educational disparities in knowledge and experience could be confronted earlier.

However, some students wondered about the practical implications of this change, asking whether 20-year-olds would be expected to attend college, or attend secondary school. SG commented:

> I was so done with high school as a senior and felt ready for college. Some students may not be that way so would need it. This is also delaying entering the workforce and becoming an adult in society which is already occurring for many who take gap years and pursue further education.

The chat transitioned well into the lecture on Piaget (Piaget and Inhelder 2008), and Vygotsky's (1999) views on stage development and the social world, with students actively arguing to understand how Piaget prioritizes the canvas of maturational processes in social development, while Vygotsky suggests the social world constructs developmental trajectories.

In Week 6, eight students attended, with several attending an academic conference. Students used newfound autonomy from Week 5 (wherein the instructor exited the chat) to interact in smaller groups, with each present student participating. The prompt asked about implementation of collaborative and direct instruction. Most students said both methods were viable, rather than taking a concrete stance, or suggesting practical ways to split the difference. User NP, said:

> This depends on what your learning goals are, and age/level of experience of the students involved. It also depends on the time you have: direct instruction can be faster; self-guided learning can take longer but could be more meaningful… if students have enough time to accomplish learning goals.

Richer peer-to-peer chat interactions occurred in the smaller group, with degree staying stable despite drop-in group-size, and transitivity (0.49) and eigen centrality rising (0.54), indicating higher scope for closed ties, and connections with influential others. In the lecture, the instructor challenged students' stance on a middle ground. Students stated necessity to equip learners with content, and opportunities to collaborate freely, to tap into expectations of a rigid school-system and prepare students to engage in constructive discourse in social arenas they may occupy in their futures, fighting back to debate the instructor. Network diagrams and centrality measures for Phase 3 are presented in Fig. 5; Table 4.
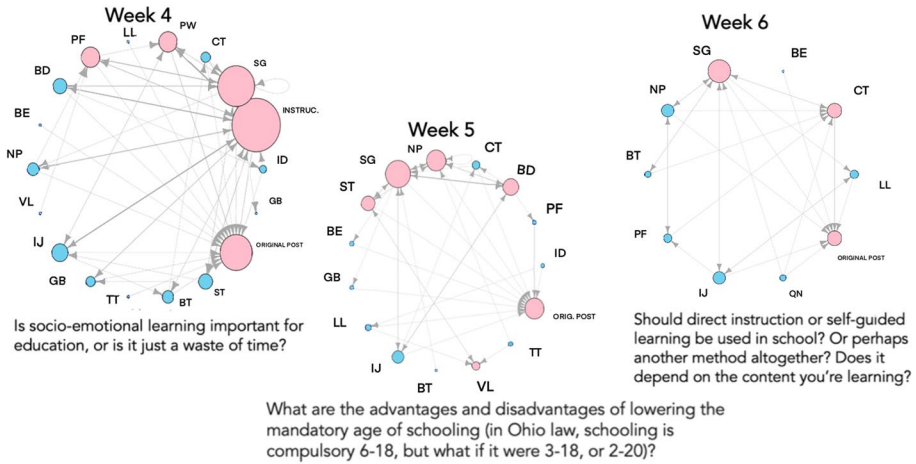
Fig. 5 Network diagrams from Phase 3

Table 4 Centrality measures, Phase 3

	Degree	In	Out	Transitivity	Eigen centrality
Week 4	6.22	3.11	3.11	0.42	0.38
Week 5	5.06	2.53	2.53	0.34	0.42
Week 6	5.2	2.6	2.6	0.49	0.54

Students in class, instructor, and designer realized a critical mass was reached in the smaller group. They collectively decided dividing chats into two groups would heighten egalitarian participation.

Phase 4

Starting Week 7, discussions were subdivided into two randomly assigned groups (chosen by distributing numbered chits). Decisions for group randomization were made to keep anonymity, a feature appreciated by students as it allowed discussing sensitive issues, and in accordance with Rand et al.'s (2011) findings which explain why iterative reformulation of social networks using a fluid network configuration amplifies collaboration. Diversification of live-chats led to mixed results, with groups displaying different participation levels as Spring Break approached.

In Week 7, the two prompts related to splitting the difference between top-down and collaborative instruction (Group 1), and domain-specificity of teaching (Group 2). 16 of 17 students participated. In Group 1, discussion was rich, perhaps owing to links students made to Week 6's topic on individual and collaborative learning. The instructor expressed students had previously not grappled deeply with splitting the difference with concrete examples, and this may have produced richer contributions, indicated by rise in transitivity (0.51) and eigen centrality (0.55). Students filled in gaps from previous discussions by stating concrete examples from experience. BT suggested quality of direct instruction and

whether it can augment collaboration and independent task performance depends on quality of teachers:

I also think it is important to consider quality of the teacher's cueing and guiding.

Another user, IJ, agreed, saying:

I have observed this as well from some of my classroom observations. Discovery approaches are very dependent on how the learning environment is set up. It's a balance between fostering curiosity and providing proper resources for students.

Group 2 weighed advantages and disadvantages of subject-specific teaching, and domain-general, unified approaches. The discussion showed high transitivity (0.47), and eigen centrality (0.61), but distribution of popular users was more hierarchical than in Group 1. Students were divided in opinion, with some, like LL, suggesting casting a wide, domain-general net in teaching would require more effort to keep learning conversations focused:

With a "wide" approach, it would be the teacher's responsibility to ensure lessons stay on topic and experiences shared by students don't get off track.

Counterpoints were raised, with one student, BD, suggesting teachers could help model conversations to keep students on task:

The teacher doesn't have to produce every example. Can't the teacher pick a theme and then ask students to share and relate more specific experiences? If the teacher wants students to learn about environmental conservation, students can identify areas in their own communities/relationship circles and create a project addressing specific issues.

Discussions in Week 8, focusing on processes of learning (how and why of dynamic concepts, and cognitive mechanisms like multi-tasking) were less uniform in collaboration across the two groups. All 17 students participated. Group 1, which discussed how and why of concepts in teaching and learning, produced lower transitivity (0.15), but showed stable eigen centrality (0.52). This means the likelihood for closed ties was reduced, but agents showed comparable likelihood to be well-connected to influential others. Students felt the prompt was vague, and responded suggesting "how" and "why" was less important, with ID saying:

I think the real question is if they learned.

Firm opinions leaving little room for open-ended discussion lowered cooperation. Group 2 showed a different trajectory in discussing multi-tasking, a topic covered in introductory graduate courses in education at the university. This group produced higher transitivity (0.40), and a comparable eigen centrality (0.56). Students engaged in a nuanced discussion, saying complex educational tasks may require targeted attention, while menial tasks may use different motor functions concurrently. User ST said:

I think we should clarify that multi-tasking is a myth related to complex tasks because of cognitive load. It is a thing for more basic tasks.

These ideas suggested basic tasks were more amenable to simultaneous performance but would not necessarily be multi-tasking as they rely on separate sensory functions. IJ, calling upon previous knowledge from the introductory graduate class, said:

From what I can recall from the class I took. They say these two actions can happen concurrently because they aren't pulling on the same cognitive functions. On one hand you are using your eyes and hands to do dishes and the other task just requires listening.

The discussion called upon concepts covered in previous classes, leading to extensive exchange. While the two discussions differed in depth, the lecture led to much questioning about sensory and social bases of thinking and action, talking about nature and nurture. Students spoke about musical and theatrical talents as constructed by both these factors, and the instructor brought in the idea of emotional history as a contributing factor. Personal and situational factors affecting learning were brought into discussions of weekly student group presentations. Two groups presented. The first screened videos of undergraduate students engaging in collaborative learning, and those watching the presentation critiqued the approach, and argued about mechanisms guiding concept development in collaboration. The second presented clips from the series *Abbott Elementary* to highlight how different pedagogies (direct instruction and collaborative learning) could be tailored to fit urban education, prompting students to ask how one can adapt collaborative instructional approaches to college settings, drawing links to the first presentation.

Seeing variety in discussion owing to different preferences/familiarities with loosely related topics, instructor and designer maintained the format for Week 9, to test if fragmentation persisted. All 17 students contributed. Group 1 discussed how teachers could react to disinterested students while implementing collaborative learning, while Group 2 focused on teacher Professional Development (PD), and whether it should be carried out as information provision or embedded into teachers' daily lives. This session occurred a week before Spring break, and students expressed exhaustion, saying the discussion was a "compulsory task," despite being told it was voluntary. As in Week 8, fragmented participation was seen, despite all students participating. Those discussing PD (Group 2) had more one-dimensional answers, suggesting aligning the nature and goals of PD to missions and goals for learning could put instructors on a concrete roadmap. User PF commented from personal experience:

> Having sat in many such PDs, I think conducting PD sessions in the way one wants to educate can be revealing. One thing revealed during these sessions is how difficult it is, even when working with adults, to maintain productivity in collaborative/constructive tasks.

The high agreement with the idea of modeling PD around a goal led to lower reciprocal exchange, showing 0 transitivity, but stable eigen centrality (0.55). While users were connected, they showed less likelihood to form closed ties. Results may be a result of the makeup of the class, primarily consisting of School Psychology students and other educators/social scientists who focused on students' mental and academic well-being in response to certain pedagogies and school climate rather than directly on teacher-training. Richer interactions occurred in Group 1, wherein members discussed ways to alleviate issues with collaborative instruction, finding greater opportunity to link ideas to previous prompts about splitting the difference between direct instruction and constructivism. Students outlined concrete solutions to model collaboration in case of off-task behavior. User LL suggested:

> I think a useful way for teachers to facilitate collaboration is using open-ended questions, which doesn't allow students to say "yes" or "no".

Others, like PW suggested prioritizing students' interest over information by tapping into topics related to their lives:

> One reason some students may not be interested in tasks is because they don't see the relevance to their life. Tying in how a task could be useful in the students' lives could help drive their interest.

These interactions showed higher transitivity than Group 2 (0.33), and slightly higher eigen centrality (0.59). The lecture, on training teachers to implement collaborative education, drew from ideas expressed in both discussions, but was instructor led. The students presented screened clips from the *Dead Poet Society*, showing how teachers can help students navigate their realities by allowing sharing experiences as equal agents, and visualizing solutions to issues they face in their real lives. Network diagrams for groups in Phase 3 are shown in Fig. 6, and weekly metrics across both groups are presented in Table 5.

Realizing students felt exhausted from a long semester and hearing their desire for more support to grapple with questions in the online chat, instructor and designer began to brainstorm ways to support concept development and cooperation within online discussions over Spring Break.
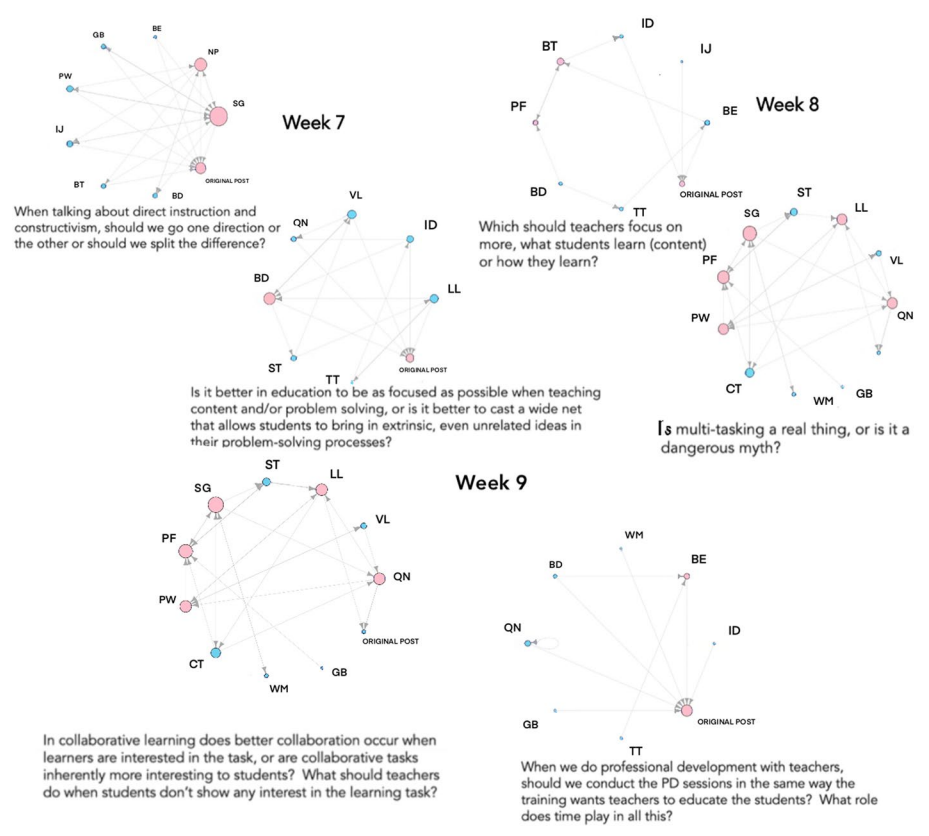

Fig. 6 Network diagrams for Phase 4

Table 5 Centrality measures, Phase 4

	Degree	In	Out	Transitivity	Eigen centrality
Week 7	4.68	2.34	2.34	0.49	0.58
Week 8	3.86	1.92	1.92	0.28	0.54
Week 9	3.77	1.76	1.76	0.17	0.57

Phase 5

Over Spring break, the instructor and participant observer connected to brainstorm ways to support students. They decided modeling the discussion through in-person commentary from the instructor could support the live-chat. In Week 10, we tested this idea by presenting a challenging question focusing on sociological theory. The discussion focused on whether cultural capital (existing content about one's cultural reality) or social capital (ability to collaborate and understand others' experiences to critique information) were more important in learning. 13 of 16 participated. Students initially struggled with the question, with Group 1 users like BD saying:

> I don't quite understand this question? Why does having limited access to cultural capital preclude critique in education?

This prompted the instructor to begin modeling the discussion through in-person commentary, explaining how cultural systems are driven by hidden agendas infused within teaching (e.g., teaching about the partition in the Indian subcontinent) that fabricate cultural capital. Room for critique through collaboration could open new pathways to learning. Such modeling led to increased collaboration. In Group 1, PW suggested providing content or cultural capital to bridge inequity was important, but allowing autonomy for critique was equally imperative:

> I would say it's important for students to understand problems associated with cultural capital and how/why many groups of people aren't allowed access to it. It's equally important to provide these students with cultural capital to not perpetuate inequity.

In Group 2, which discussed contrast between content and critique, valid questions about mutual exclusivity of cultural and social capital were raised, with NP commenting:

> Are the two mutually exclusive? Is the argument that, because cultural capital maintains boundaries of, and limits access to, exclusive spaces, practicing cultural capital is in opposition of practicing social capital?

This prompted responses suggesting cultural capital was not necessarily bounded within spaces of privilege, but ability to critique it while important, may be limited in communities without resources. Group 1 showed transitivity of 0.41, while Group 2 showed a lower tendency for closed ties (0.29). Eigen centrality was higher in Group 1 (0.61) compared to Group 2 (0.51).

The discussion transitioned into a lecture on the nature of the hidden curriculum, with the instructor moving ahead of the syllabus to explain how radical education, could relate to the idea of giving students the freedom to critique ideas through development of social capital. The instructor went into the history of radical education, which is rooted in the ideas of Ivan Illich (1971), and the cybernetics movement in the 1970s (Tilak et al. 2021).

The following presentation on direct instruction and collaboration prompted links to promoting learning through critique, and presented video clips from the classic film, *Karate Kid.* Students watching highlighted how Mr. Miyagi engaged in a direct instruction process, and how English language learning could best be carried out through a conversational, collaborative approach.

In Week 11, the same format was maintained. Students were enamored by the discussion \about radical education and cybernetics and had enthusiastically written reaction papers about the ideas of Illich and other cyberneticians like Gregory Bateson to explain processes associated with learning and mental well-being through collaboration. The weekly prompt, focusing on applications and risks of radical education calling for restructuring of schools to be based on informal project-based approaches, produced considerable knowledge-sharing. 16 of 17 participated. In Group 1, students linked critique through radical education to critical race theory (CRT) approaches that have become controversial in the U.S., saying giving students an opportunity to critique a neutral canvas of ideas is often incorrectly tied to liberal agendas. User ST commented:

> The CRT craze is a good example. Teaching history with multiple racial perspectives is not CRT but it is a label that is being used as a catch-all for any content critical of U.S. institutions.

Students responded saying implementing such processes in individual classrooms could be risky, inviting criticism from fellow colleagues, and even parents. However, VL raised a salient response, suggesting implementing any new practice in an individual classroom invited difficulties, highlighting how "sticking to a status quo" often conflicted with ideas of radical education:

> Teachers may already be ostracized for any number of things they do in their classroom.

In Group 2, members discussed potential limitations of radical education. Comments suggested being conditioned to using a top-down, direct instruction approach may cause instructors to panic when students do not show interest in critique. NP suggested:

> Some students might have only been motivated by emulating the traditional classroom dynamic to earn points, they might be intimidated or uncomfortable breaking the norm.

Students also mentioned the role of the home in transforming education. While pivoting radical pedagogy may transform students' thinking when successful, such change may not be universally amenable to parents. When asked about the merit of success in spurring student critique, and the effects of the home, PF responded:

> I think some of those "successes" might exacerbate conflicts between teachers and parent/admin.

While discussions were constructive and invited intense questioning, Group 1 showed lower transitivity (0.22) than Group 2 (0.48), and slightly lower eigen centrality as well (0.43 compared to 0.54). Participation in both chats became more egalitarian, indicated by higher number of nodes with in-degree higher than average, Network diagrams, and average centrality metrics are presented in Fig. 7, and Table 6, respectively.

The lecture that followed further expanded on radical education, with students discussing ways to apply project-based approaches to the constraints of current educational environments, trying to concretize the ideas discussed in the chat. Seeing how transitivity and
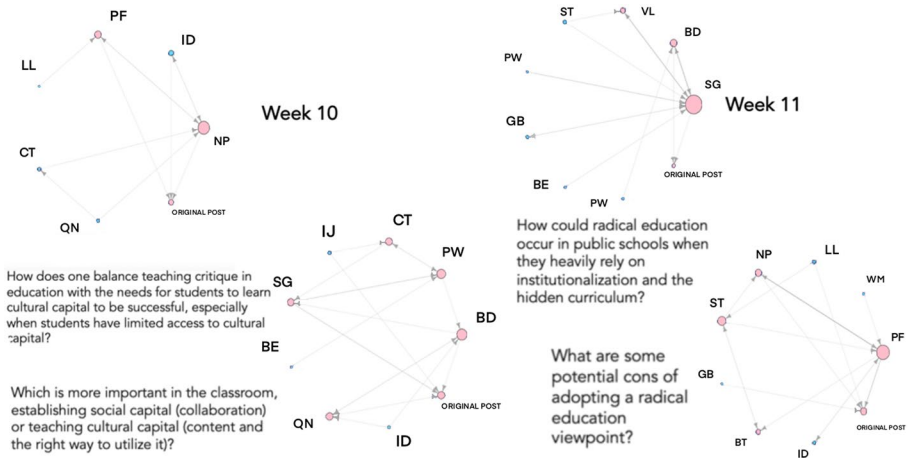
Fig. 7 Network diagrams for Phase 5

Table 6 Centrality measures, Phase 5

	Degree	In	Out	Transitivity	Eigen centrality
Week 10	3.45	1.73	1.73	0.35	0.56
Week 11	3.01	1.51	1.51	0.35	0.49

participation stabilized when autonomy for free interaction was balanced by modeling, we maintained bipartite discussions and provided slightly higher autonomy to students in Phase 6.

Phase 6

Seeing how students came to appreciate instructor commentary of prompts, we provided options to students to self-select groups in the final weeks to complement instructor guidance with autonomy. We thought this would enable agency to respond to prompts. In Week 12, rather than choosing groups by informing each other, students counted off in ones and twos, maintaining anonymity. 14 of 17 participated. Group 1 discussed motivation, which has become a popular focus in fields like Educational Psychology. Group 1 discussed the unmotivated student, trying to decode whether disinterest in a particular topic equaled being "unmotivated". Students grappled with concepts from motivation theories (Anderman and Dawson 2011), and argued amotivation could exist when students could not see the utility of tasks. User IJ suggested motivation was context-specific:

> You can take the same so called "unmotivated" student and place them in a different/ more engaging environment and their behavior would be different.

Others like LL concurred, saying larger contexts (home, neighborhood) could affect students' tendencies to perceive they can succeed at something, find something they enjoy, or detect tasks could have value for their futures, calling for a situated study of mechanisms sparking interest:

There are a lot of factors that may make a student seem unmotivated (lack of interest, don't have the skills to complete the task, things going on at home that are impacting social emotional well-being, etc.).

Group 2 discussed how teachers can make sure they factor students' interest over topics as opposed to content knowledge, and whether this was their responsibility. Students agreed teachers needed to know who their learners are as people to understand what engages them and make spontaneous links to topics or examples they might find accessible. BE expressed this idea of teaching the "whole child":

I think teachers can attempt to make the curriculum interesting by relating it to the students' own lives and experiences.

PF provided a counterpoint, saying making content engaging could be amplified by a teacher's passion, heightening the tendency to convince students that material is valuable:

A teacher's demonstrated interest in the subject is how they prove to students that the curriculum is worth their time.

The two related chats complemented the lecture, which focused on biological, social, and cognitive aspects of developing interest in learning. The instructor mentioned the idea of emotional history and posed Vygotsky's (1999) theory as a counterpoint to motivation, which may subdivide mentation and behavior into separate entities, as opposed to treating them as integrated. Students and instructor were interested in applying the idea of emotional history to moral education and service learning, trying to understand why grappling with sociomoral issues at a younger age may spur nascent citizens to think critically in their futures about issues like food security and other societal hardships. The student presentation screened clips from the *Freedom Writers Movement*, explaining how getting to know who students are can help practitioners find ways to engage them.

Both Group 1 and Group 2 showed high transitivity (0.34 and 0.58). The average degree was higher compared to Weeks 10 and 11 (4 in both groups). Participation became egalitarian, with a greater proportion of users showing in-degree greater than average. Eigen centrality shot up to 0.68 in Group 1, and 0.69 in Group 2 (average of 0.68), indicating members were well-connected to influential others.

In Week 13, students self-selected groups by choosing a preferred prompt in private, and posted to that group, determined to stay anonymous. The weekly topic was the role of diversity in education. 16 of 17 students participated. The discussion question in Group 1 focused on the role of parents in schools, and whether involving them in policy decisions would help serve the needs of their communities. An argumentative discussion ensued, with some users, like SG raising the case of special education programs:

Parents should have a right to participate in education. At least in special education, parents are required to have a right to participate in a child's special education like consent to evaluation, participate in evaluation meetings, IEP meetings participation, etc.

Other users suggested a parent-involvement infrastructure was already in place, and better mediating discussions parents have at school board meetings would help parents have some say in their child's education:

Most parents can share at school board meetings though. The parents that have the time and energy to engage in any formal representation will just be the same that show up for school board gatherings.

In Group 2, participants discussed whether parents should have a say in which practitioners are hired to teach their children. Some users like CT took up a community-driven perspective, suggesting parents' limited knowledge of driving forces behind teacher training would not equip them to make such decisions:

> I think this would be difficult to accomplish given how many opinions parents have; additionally, parents are not always well versed in educational training or qualifications so I do not know how helpful that input would be.

BD expanded this notion, suggesting political views parents could possess as individual/family units may influence school practices in undue ways, increasing the chance for polarized practices to be perpetuated:

> It would be a political nightmare if parents got involved in the hiring process. That can open doors to unfair hiring practices and undue influence from parents if they had the power to say yes/no.

Both Groups 1 and 2 showed high transitivity (0.41 and 0.45 respectively), and comparable average degree (3.6 and 3 respectively) and in-degree (1.8 and 1.5). Eigen centrality in Week 13 was comparable to Week 12 and balanced across both groups (0.54, 0.58). The following lecture transitioned from understanding parents' roles in education, to understanding how culturally relevant practices could be implemented in school through fostering collaboration and understanding diverse cultural experiences. The instructor introduced the work of Gutierrez and Rogoff (2003), who design culturally relevant Zones of Proximal Development by allowing connections to be made by students to their own experience through dramatic play. The student presentation screened clips from *Remember the Titans*, which described conflicts between all-black and all-white football teams when they were fused, to help understand how cultural experiences can be negotiated to spur cooperation. Network diagrams for Phase 6 are provided in Fig. 8. Average weekly metrics are provided in Table 7.

Phase 7: Feedback

An end-semester feedback chat was conducted on Reddit in Week 14. 13 students were present. Three questions were provided. Research assistants used qualitative methods to inductively (Bingham and Witkowsky 2021) create themes from response content provided. The first question asked how using Reddit spurred learning. Two coders analyzed the 12 responses and discovered two themes, namely synchronous chatting, and Internet influenced learning. Agreement percentages for each variable, and percentage of responses is provided in Table 8.

Participants like BE suggested synchronous chatting, and how it was adapted, dividing the class into smaller subgroups helped learning:

> Participating in the Reddit learning community this semester was a new and interesting experience for me! I have not engaged in anonymous, online chatting in any other class before, and I had a few takeaways. I liked how we made the adjustment to having two questions that resulted in smaller group discussions.

Others, like ID suggested communicating on popular Internet tools helped understand how informal interactions on platforms may also be educational:
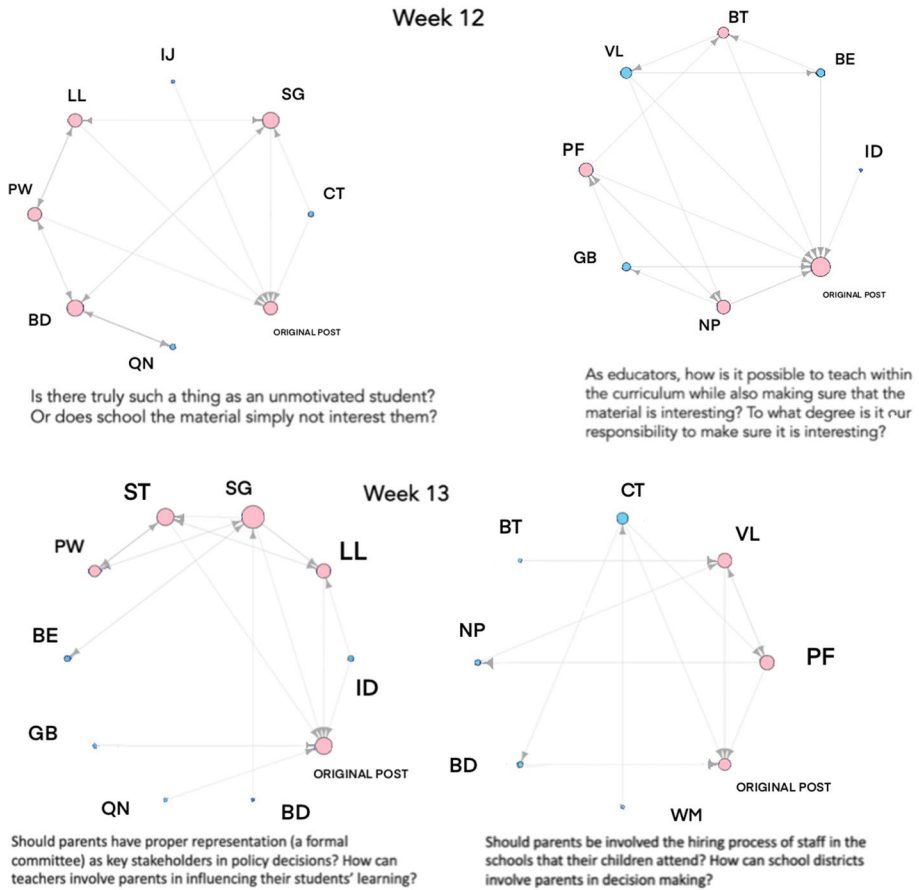
Fig. 8 Network diagrams, Phase 6

Table 7 Centrality measures, Phase 6

	Degree	In	Out	Transitivity	Eigen centrality
Week 12	4	2	2	0.46	0.68
Week 13	3.3	1.7	1.7	0.43	0.56

Table 8 Feedback for Question 1

Mechanism of Learning	Agreement %	Sample %
Synchronous chatting	83.33%	66.66%
Internet-influenced learning	100.00%	33.33%

Reddit has impacted my experience because I do participate more in the community than in the classroom. It has given me a different outlook since I never thought of reddit being educational.

Table 9 Feedback for Question 2

Strengths of Reddit	Agreement %	Sample%
Anonymity	91.66%	100%
Informal interaction	83.33%	58.33%
Synchronous live chat	100%	16.66%

Table 10 Feedback for Question 3

Limitations of reddit	Agreement %	Sample %
Speed of live chat	91.66%	50%
Logistics of setup	100%	41.66%
Disengagement due to voluntary participation	100%	50%

The second question pertained to Reddit's strengths. Three themes emerged, namely anonymity, synchronous live-chatting, and informal interaction. The percentage of responses, and agreement metrics are provided in Table 9.

Users like BE suggested anonymity enabled unfiltered sharing of ideas, highlighting the role of authentic emotions in spurring shared languages:

One strength is that anonymity may have encouraged people to share thoughts they may not have if it were a traditional discussion.

Others suggested the fast-paced, non-traditional chat allowed multiple individuals to flesh out their thoughts simultaneously, creating a stream of developing ideas:

I think anonymity and how it allows people to flesh out thoughts simultaneously is its biggest strengths.

The third question pertained to the limitations of the Reddit community. Upon analyzing responses, coders observed three themes: speed of the live-chat, logistics of classroom setup, and disengagement owing to voluntary participation. Agreement metrics and percentage of responses are provided in Table 10.

Some users like TT, concomitant with concerns expressed in Week 2, suggested speed of the chat made them struggle to find a good point to enter conversations:

One thing I struggled with was jumping in on the live discussions because of the speed that the different thoughts and ideas.

User SG suggested that passing around chits to randomly assign groups, and being able to peek into others' computers while posting to the live-chat in class were aspects of classroom setup limiting anonymity, and that randomization led to less freedom in picking prompts:

A limitation is that we are completing the Reddit posts during class. It may result in someone seeing who you are if you sit next to someone. Another limitation is that groups were randomized. I did not like this as I may not have wanted to answer the question and answer the other one.

This may have explained the disjointed participation for the loosely related prompts in Week 8 and 9. Others like BD said options for voluntary participation in the Reddit discussion, and anonymity often caused people to disengage:

> Sometimes, people don't respond, or are forced to produce something for the sake of participating.

Despite claims of disengagement, live-chat participation gradually increased and stabilized with time, as discussions grew more egalitarian and reflective. Responses of students in the feedback session suggested the informal, dynamic online community was beneficial, enabling constructive knowledge-sharing in an open-ended manner, seamlessly transitioning into the lecture. The final lecture focused on implementing informal platforms like Reddit in educational settings, blurring lines between everyday online interactions and educational activities. Students suggested they only discussed about what they learnt in class if it incidentally arose in conversations and suggested one could "appear" engaged in the online conversations they have but really be disconnected from them, doing other things on their devices (a limitation of the Reddit chat raised by students). This led to discussion about claims that the hyperlinked nature of the Internet led to maladaptive mental health outcomes (Haid and Allen 2020). Students and instructor agreed overdiagnosis of ADHD and interests of pharmaceutical companies may heighten these concerns, saying while there are concerns with the proliferation of misinformation on the Internet, it may provide children with specific interests and cultural languages from a young age. The discussion pointed to the purpose of inserting a social media chat into the curriculum; to equip students with skills to engage in civil discourse and problem-solving in an information-saturated society.

Overall Evolution of Network Metrics

Over time, despite subdividing discussions, the average degree became stable as we approached Week 10 and understood how to balance authority and autonomy by modeling the student-led chats on Reddit (Fig. 9).

Transitivity fell in Phase 2, when we tested asynchronous blogging, and rose until Week 7, when instructor and designer decided to implement subdivision of chats, seeing a critical mass in Week 6 (end of Phase 3). As Spring break neared in Week 9, students expressed exhaustion, with average transitivity dropping. In Phase 5, participants appreciated support from ongoing instructor commentary and began to actively post. Participation became more egalitarian in Phase 6 when support of the instructor was complemented with self-selection of prompts. This autonomy gave students more agency to discuss ideas knowing they had a choice to pick topics. Eigen centrality showed steady increase, suggesting agents within the network were more likely to be connected to popular users. While the instructor was initially involved, withdrawal from the conversation allowed talkative students to bring quieter peers into the discussion, through legitimate peripheral participation (Lave and Wenger 1991). Adapting the network by random reshuffling produced greater chance for positive co-dependence to guide the online discussion, amplified by self-selected groups. Changes in transitivity and eigen centrality are depicted in Fig. 10.

There was almost perfect correlation between degree and eigen centrality that remained steady throughout (between 0.91 and 0.98). Weekly correlations are presented in Table 11.

With regards to the number of participating students, we saw despite the chat being voluntary, there was steady rise in participation, with most students present partaking in the dynamic live discussion as the end of the semester approached. Below, we provide a graph
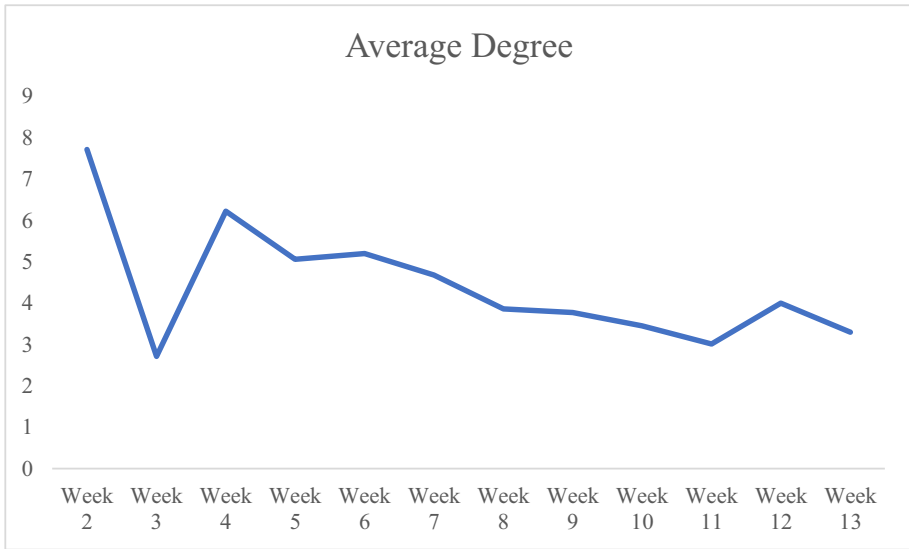
**Fig. 9** Weekly graphical representation of average degree
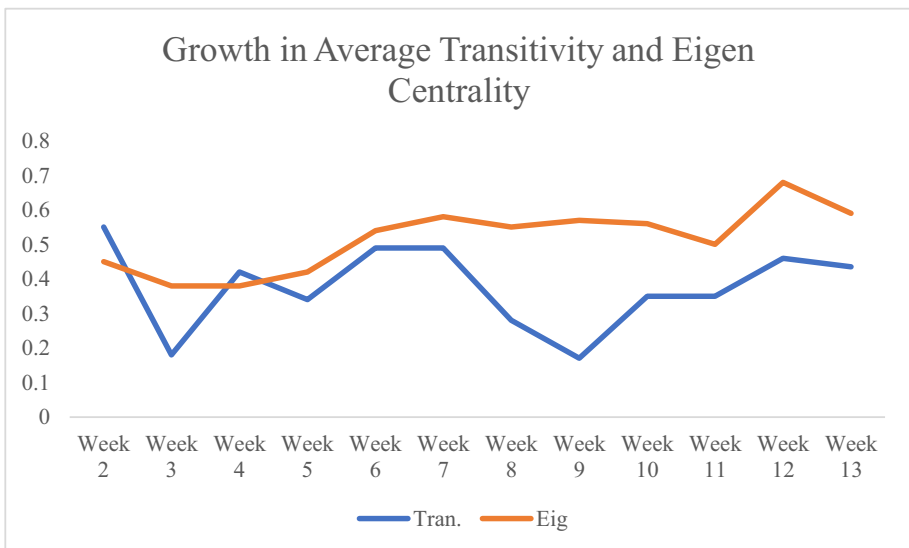
Fig. 10 Weekly graphical representation of average transitivity and eigen centrality

depicting the weekly percentage of present students participating in the discussion (Fig. 11, see Table 12 for attendance metrics).

While students actively engaged in chatting, anonymity led to a reduction in peer review posts in the second half of the semester. Students treated peer review as a cursory task, and limitations of such activities in an anonymous setting were expressed

Table 11 Weekly average correlations between centrality measures

Week/ Metrics	Eigen. and deg.
Week 2	0.98
Week 3	0.95
Week 4	0.95
Week 5	0.94
Week 6	0.97
Week 7	0.98
Week 8	0.91
Week 9	0.94
Week 10	0.96
Week 11	0.96
Week 12	0.97
Week 13	0.95
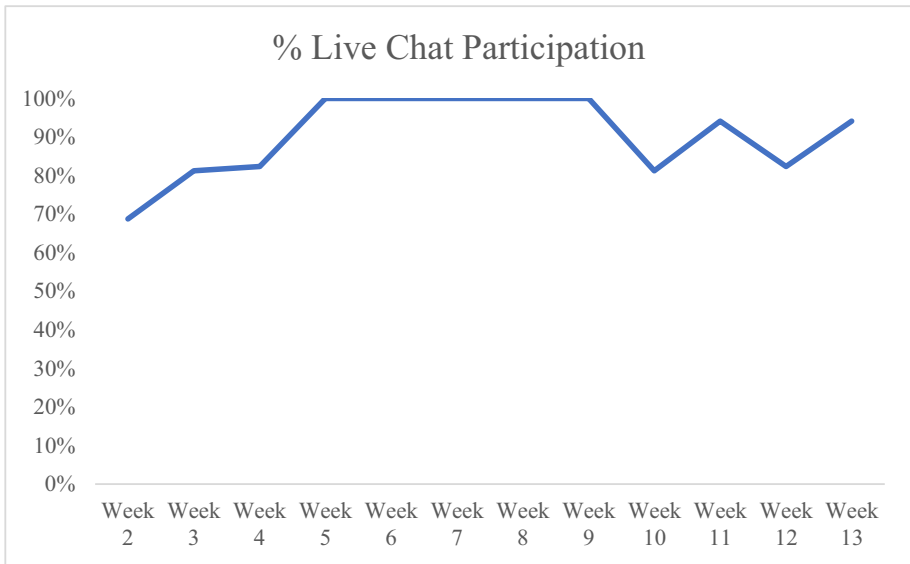
Fig. 11 Weekly percentage of students participating in live chat

in the feedback. Most respondents stuck to a fixed rubric (stating strengths and limitations) while commenting. While some weeks saw extensive responses (starting off with 14 posts), others showed a decrease (falling to 10 posts in the last round) (see Fig. 12; Table 13). Low participation stands in contrast to the live-chat, which encouraged spontaneous, voluntary participation allowing students to grapple with ideas they would present and write about and discuss them at a deeper level in the lecture.

Our results suggest redesigning the live-chat component of a technology-supported graduate-level psychology class enabled creating a cohesive learning community that could co-construct online and face-to-face dialogues through a place-space dialectic.

Table 12 Number of students participating in the live chat

Week	Participation	Present	% Participation
Week 2	11	16	68.75
Week 3	13	16	81.25
Week 4	14	17	82.35
Week 5	17	17	100
Week 6	8	8	100
Week 7	17	17	100
Week 8	17	17	100
Week 9	17	17	100
Week 10	13	16	81.25
Week 11	16	17	94.12
Week 12	14	17	82.35
Week 13	16	17	94.12
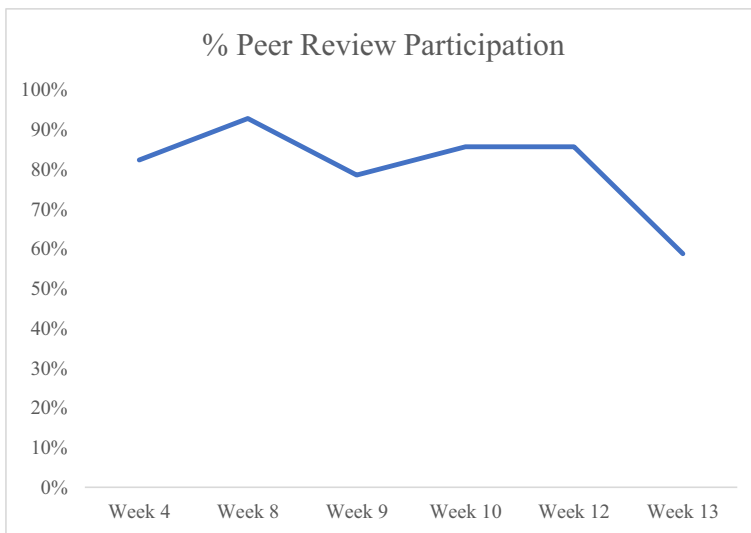
Fig. 12 Percentage of peer review posts in applicable weeks

Table 13 Number of peer review participants for applicable weeks

Week	Participation	Total Expected	% Participation
Week 4	14	17	82.35%
Week 8	13	14	92.85%
Week 9	11	14	78.57%
Week 10	12	14	85.71%
Week 12	12	14	85.71%
Week 13	10	14	58.82%

Discussion

Our study, that applies cybernetics, participatory action, and network science to educational contexts, answers three hypotheses, and suggests ways to expand the use of social network analysis in educational settings (Ouyang 2021) to incorporate the possibilities of participatory action research and second-order cybernetics (Tilak and Glassman 2022). Firstly, we ask whether participatory design using social network analysis as weekly feedback to adapt online discussions in a graduate classroom helped produce tendencies to form closed ties, between more than two individuals. Our results answer **H1**, show transitivity becomes stable as the network is adapted, constantly evolving to meet needs expressed by students. Since proportion of nodes showing greater than average in-degree increased as autonomy and authority were balanced, our findings successfully fulfil **H2**, which suggests participatory design promoted egalitarian participation with time. Rise in eigen centrality indicates agents grew more likely to connect to influential others, answering **H3**. These results fall in line with Rand et al.'s (2011) findings, which suggest that adapting the structure of a collaborative environment to increase the variety of interactions can stabilize cohesion and cooperation over time, by adapting the structure of the field of interaction to spur such communication.

Students were able to challenge stances made by the instructor, and grapple more deeply with issues discussed in the chats during the lecture. As students began to realize linkages between their presentations, the lecture, and their reaction papers could be further forged and strengthened through interaction in the optional live-chat, the proportion of participating community members began to increase despite activity being ungraded. When students encountered ideas interesting to them, they were prompt in writing reaction papers. This created a space-place dialectic (Glassman and Burbidge 2014) in the classroom, with online and face-to-face interactions co-constructing one another, answering our exploratory research question (**ERQ1**). Providing students with pathways towards shared experiences by adaptively restructuring online discussion may heighten collaboration; a process that amplifies when probability to develop new standpoints/ideologies is increased. By showing that network analysis can be used as a modelling facility to alter technology-assisted classroom activities as lessons progress and heighten both technology-assisted and lecture driven conversations, we augment current approaches to iterative design that are demarcated by well-defined phases of curriculum implementation and analysis (Byrne and Tangney 2010; Evans et al. under review; Glassman et al. 2013; Lui and Slotta 2014; Miller et al. under review) to create a continuum of implementation and design by using ideas stemming from second-order cybernetics and participatory action research. Our efforts aim to equip students with the skills to navigate highly polarized online environments by mimicking these feedback loops using network analysis and participant observation to model ongoing interactions.

Limitations

This study has a few limitations. While sample size is small, the nature of the study, which involves adoption of a radical curricular design approach, may be more amenable to application for smaller classes. A large number of students may limit their freedom to modulate online activities to meet individual needs. While we elaborate extensively on mechanisms of learning by explaining the link between lectures, discussion posts and student presentations using narrative inquiry design, we do not analyze quality of live chats using a coding scheme.

Further research could understand whether the reflectivity of posts (Tilak et al. 2020) increased with time and fostered increased network ties, using coded metrics as a node attribute, to map the growth of reflectivity in the weekly sociograms using exponential random graph models (ERGM). Since gender distribution comprised more female students, homophily (tendency for interactions between those of same gender) could be investigated, but lies outside the scope of this study, which investigates whether changing the design structure of an online discussion week-to-week using network analyses and ethnography of anecdotal classroom experiences may guide a learning community towards constructive collaboration.

Conclusion

Educational research has often been deemed a difficult science (Berliner 2002), since those observing classrooms and implementing interventions must consider humans they study as systems that constantly evolve, embedded with complex social environments, in preparing them to productively navigate their own realities (Tilak and Glassman 2022). With the Internet becoming a publicly available tool, there have been both concerns and hopes arising from its use, requiring educators to account for these experiences that students have as historical actors in a highly information-saturated society. In this paper, we suggest that course designers can mimic the ongoing of responses of the cybernetic feedback loops produced by new media platforms through the use of tools such as network analysis and participant observation as modelling facilities (Pangaro 2008; Pask 1975) guiding design through second-order approaches. Such an approach can help create norm-driven educational environments that may equip students with skills to navigate a complex, interconnected world with a critical eye.

Declarations

Conflict of Interest The authors declare that there is no conflict of interest associated with the present study.

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