Classroom Interaction Geography: A Case Study

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Abstract: The study of classroom discourse is central to understanding and supporting effective teaching practice. Recently, researchers have begun to explore the spatial dimension of classroom discourse. However, this work emphasizes the lack of methods, particularly visual methods, to fully explore the spatial dimension of classroom discourse. This paper uses an approach to studying collaborative interaction we have developed called interaction geography to revisit a classic case known as "Sean Numbers" from the work of renown teacher educator Deborah Ball. Our analysis highlights the value of interaction geography to visually and dynamically explore the spatial and temporal dimensions of classroom discourse. We also make a data visualization of this work available to support further discussion and work to describe classroom interaction geography.

Introduction

The study of classroom discourse is central to understanding and supporting effective teaching practice (Cazden, 2001; Horn & Little, 2010; Lampert & Cobb, 2003; Philip & Garcia, 2013; Ball, 1993). Recently, researchers have begun to explore the spatial dimension of classroom discourse. For example, some show that where teachers intervene in student talk within a classroom is critical to understanding how phenomena like teacher's monitoring routines support student learning (Ehrenfeld & Horn, 2019). Others describe notions such as spatial pedagogy to analyze how regions of a classroom take on particular meanings through repeated interactions and how teachers' use of space supports effective classroom teaching (Lim et al., 2012). Still others demonstrate that making ideas such as spatial pedagogy visible can support teachers' reflective professional practice (Martinez-Maldonado, 2019). However, this work emphasizes the lack of methods, particularly visual methods, to fully explore the spatial and temporal dimensions of classroom discourse simultaneously to account for what we describe as classroom interaction geography.

In this paper, we revisit a classic case known as "Sean Numbers" from the work of Deborah Ball (Ball, 1993). Sean Numbers describes a class discussion in an elementary school classroom which begins when one student, Sean, offers a conjecture that the number "6" is both an odd and an even number. Subsequently, the class discussion focuses on a debate about even and odd numbers, in which other students disagree with Sean's conjecture. Ultimately, Ball and her students define 6 as a "Sean Number," which is any number that has "an odd number of groups of two" (Ball, 1993, p. 387). This discussion has been revisited and used to illustrate the importance of and challenges associated with respecting children's thinking (Ball, 1993), with supporting mathematical discourse and reasoning (Bass, 2005), and with implementing accountable argumentation (Horn, 2008). The case also exemplifies an early adoption of video analysis as a method to study classroom discourse; indeed, this approximately 10-minute record of pedagogical practice has been analyzed by researchers and practitioners in many settings (Ball et al., 2014). Yet, previous analyses of this case — and nearly all studies of classroom discourse since — did not account for the spatial dimension of classroom discourse.

We revisit Sean Numbers — and particularly a seven-minute sequence of interaction from Ball's original work — to illustrate the relevance to classroom research of a new approach to studying interaction: *interaction geography*. This data was originally collected by Deborah Loewenberg Ball and used here with special permission from Mathematics Teaching and Learning to Teach, University of Michigan (2010). Our analysis highlights the value of interaction geography to visually and dynamically explore the spatial and temporal dimensions of classroom discourse simultaneously. We also make a data visualization available, in an effort to support further discussion and future work concerning classroom interaction geography. Altogether, our work joins theoretical and methodological insights from the learning sciences with research on teaching and teacher learning in ways that reflect this year's ICLS theme.

We begin by reviewing the situative perspectives on teaching practice and the methodological approach of interaction geography that ground our work. Next, we organize our analysis around three figures that progressively demonstrate technical methods of interaction geography and the phenomena and questions that are made available using interaction geography. We then explain how to access and use the data visualization accompanying this work and offer next steps to address inherent limitations of this new work.

Theoretical framework

Teaching as a situated social practice

We draw from an established body of work that illustrates how teaching is a culturally and historically situated activity constituted in relation to learners and communities (Cazden, 2001; Lampert & Cobb, 2003; Lave & Wenger, 1991; Ma & Singer-Gabella, 2011). This literature emphasizes the social dimensions of teaching, viewing student learning as an interactional accomplishment between teachers, students, and the institutional settings in which they work (Cohen, 2011; Greeno, 1998; Gresalfi et al., 2009; Horn & Little, 2010; Jurow, 2004). Scholars in this tradition often analyze classroom teaching with an emphasis on discourse, using detailed video and audio records to engage in conversation or interaction analysis (Cazden, 2001; Erickson et al., 2017; Hall & Stevens, 2016; Jordan & Henderson, 1995). Importantly, researchers studying classroom discourse have begun to expand from an analysis of language alone to the analysis of multiple modalities to better describe the situated nature of teaching practice. As a result, some have explored the spatial dimension of classroom discourse. For instance, Ehrenfeld and Horn (2019) developed a framework to conceptualize teachers' monitoring routines during groupwork, highlighting the effects of the teacher's location within a classroom on the nature of student talk. Likewise, in their multimodal discourse analysis, Lim and colleagues (2012) use "spatial pedagogy" to describe how teachers ascribe meaning to zones of a classroom through their positioning and use of space.

Collectively, this literature highlights the importance of studying classroom discourse to understand and support effective and equitable teaching practice. However, this body of work lacks more dynamic visual methods to explore and describe the spatial and temporal dimensions of classroom discourse simultaneously. Accordingly, we address this gap by incorporating interaction geography into a situated analysis of classroom discourse.

Interaction geography

Interaction geography is a new methodological approach developed in the learning sciences (Shapiro, Hall & Owens, 2017). This approach extends research that studies how participants' physical movements can be embodied resources for sense-making and learning (see Bang et al. 2007; Enyedy et al., 2015; Hall & Stevens, 2016; Keifert & Stevens, 2019; Marin, 2013; Silvis, Taylor & Stevens, 2018).

Specifically, interaction geography consists of *Mondrian Transcription*, a method to transcribe and represent data about people's movement and conversation over space and time, and the *interaction geography slicer (IGS)*, a dynamic visualization tool that allows for exploratory analyses of participants' movement and conversation in relation to audio and video. Interaction geography has been previously used in museum environments to study visitor's engagement and use of social media and to support reflective professional practice and design (see Shapiro & Hall, 2018). Likewise, the IGS has also been used to support a method to teaching data ethics for data science education called Re-Shape and to dynamically visualize large-scale data sets related to New York City's Stop-And-Frisk Program (Shapiro et al., 2020; Shapiro & Pearman, 2017).

In this paper, we propose using interaction geography to support situative analyses of teaching and classroom discourse. We conjecture that examining spatial and temporal dimensions of classroom interactions through interaction geography may open new avenues of inquiry into teachers' practice and student learning.

Classroom interaction geography

To illustrate the possibilities of classroom interaction geography for analyzing classroom discourse, we organize our analysis around three figures that progressively illustrate different ways of using interaction geography to study seven minutes from the class discussion of Sean Numbers introduced above. Notably, three minutes of the ten-minute discussion are not included because students' locations were not available in the video record.

Teacher movement over space and space-time

Figure 1 shows the teacher's movement during this seven-minute sequence over a *floor plan view* and a *space-time view*. Namely, the left part of the figure is the floor plan view; it shows a simplified floor plan of a classroom. In other words, readers are looking down on four groups of desks (with four or five desks in each group) and a chalkboard that extends the length of the classroom, on the right. There are seventeen students and one teacher seated at desks, depicted as ovals. Five individuals — Sean, Mei, Nathan, Cassandra, and the teacher — are highlighted in color; all other students are shown in grey. In addition, the purple line represents the teacher's movement across the classroom, indicating where she walks during the discussion.

The right part of the figure shows a *space-time view* (Hagerstrand, 1970), which reveals the teacher's movement over a timeline, in minutes and seconds, along the horizontal axis. The vertical axis in the space-time view corresponds to the vertical dimension on the floor plan. We have annotated the figure to help read the space-

time view. The beginning of the space-time view (0:00-2:30) shows a flat horizontal line, which indicates that the teacher remained seated at the desk in the lower right of the floor plan. The next segment of the space-time view (2:30-4:45) shows the teacher standing near the chalkboard, moving slightly near the lower right corner of the floor plan. From approximately 4:45-5:15 in the space-time view, a line extends upwards; this indicates the teacher's path across the classroom, corresponding with the dotted arrow marked on the floor plan. During these 30 seconds, she walked along the chalkboard across the classroom (thus her movement extends from bottom to top in both views). For the remainder of the discussion, the teacher stayed on that side of the classroom.

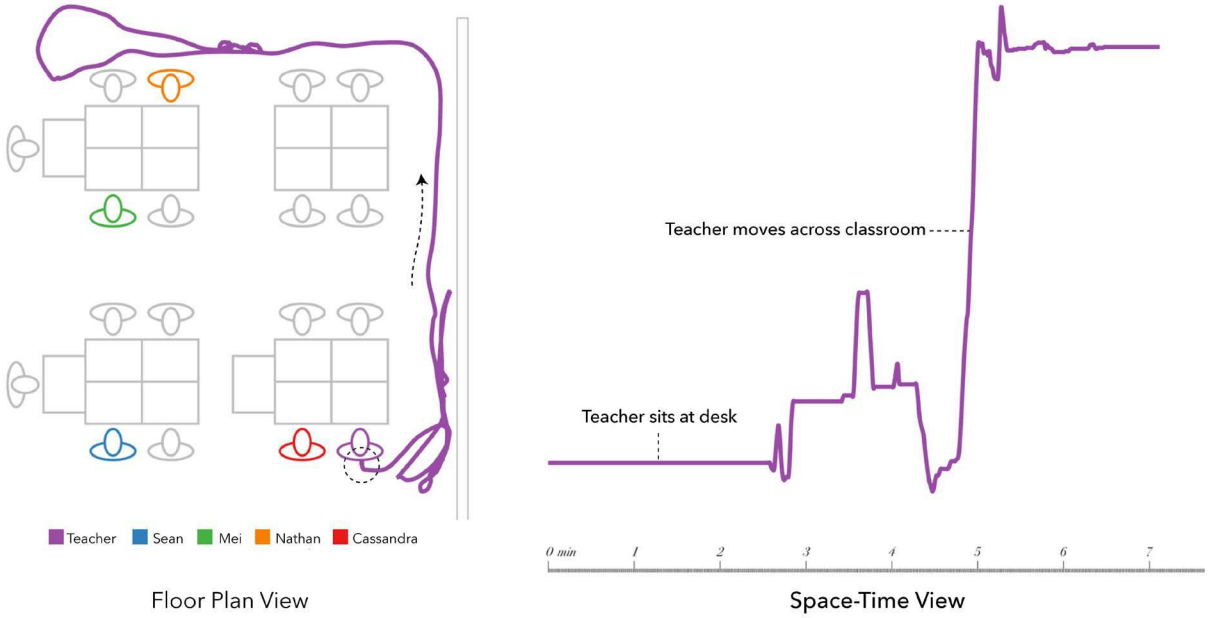

Figure 1. Teacher movement over space and space-time during a seven-minute sequence of classroom discussion. On the left, a floor plan view shows where the teacher (purple path) moves, as well as the positioning of students and furniture within the classroom. On the right, the teacher's movement is extended over space-time, with the vertical axis corresponding to the vertical dimension on the floor plan *(Data used with special permission from Mathematics Teaching and Learning to Teach, University of Michigan).*

Existing research uses similar floor plan views to characterize the positioning of teachers at moments in time or to produce heat maps that show the accumulation of teachers' movements over long periods of time; these reveal hot spots, or zones where teachers are most active with their students (see Lim et al., 2012; Martinez-Maldonado, 2019). For example, the floor plan view in Figure 1 illustrates that the teacher did not approach the group in the lower left corner during this sequence of interaction. The space-time view has not been used to study classroom interaction and addresses many limitations of conventional floor plan views. Most notably in this case, the space-time view provides ways to interpret teachers' movements over space and time to see the pace and sequential organization of their movements. For example, the space-time view in Figure 1 illustrates that the teacher spent much of her time on either side of the classroom but traversed the room quickly part-way through the discussion. Moreover, the space-time view begins to raise questions about how the sequential and spatial organization of teachers' movements are connected to classroom discourse. For example, in this case, how did students' participation patterns shift as a result of the teacher's proximity to different groups?

Mondrian Transcription

Building on the representation of movement presented in Figure 1, Figure 2 adds *Mondrian Transcription* to represent both movement and conversation over space and time. The figure is composed of six images, each highlighting different participants. Figure 2A superimposes the teacher's movement (in purple, as shown previously) over the movement of four focal students (in gray) who move or speak during the class discussion. Figure 2B shows the teacher's movement but also includes each of her conversation turns, represented as purple rectangles along her movement path in the floor plan and space-time views to indicate when and where she made those utterances. The height of each rectangle indicates the length of each turn of talk. Figures 2C-F similarly show the movement and conversation of the four focal students — Sean, Mei, Cassandra, and Nathan. Data in each image is scaled identically allowing comparative analysis of each participant's movement and conversation.

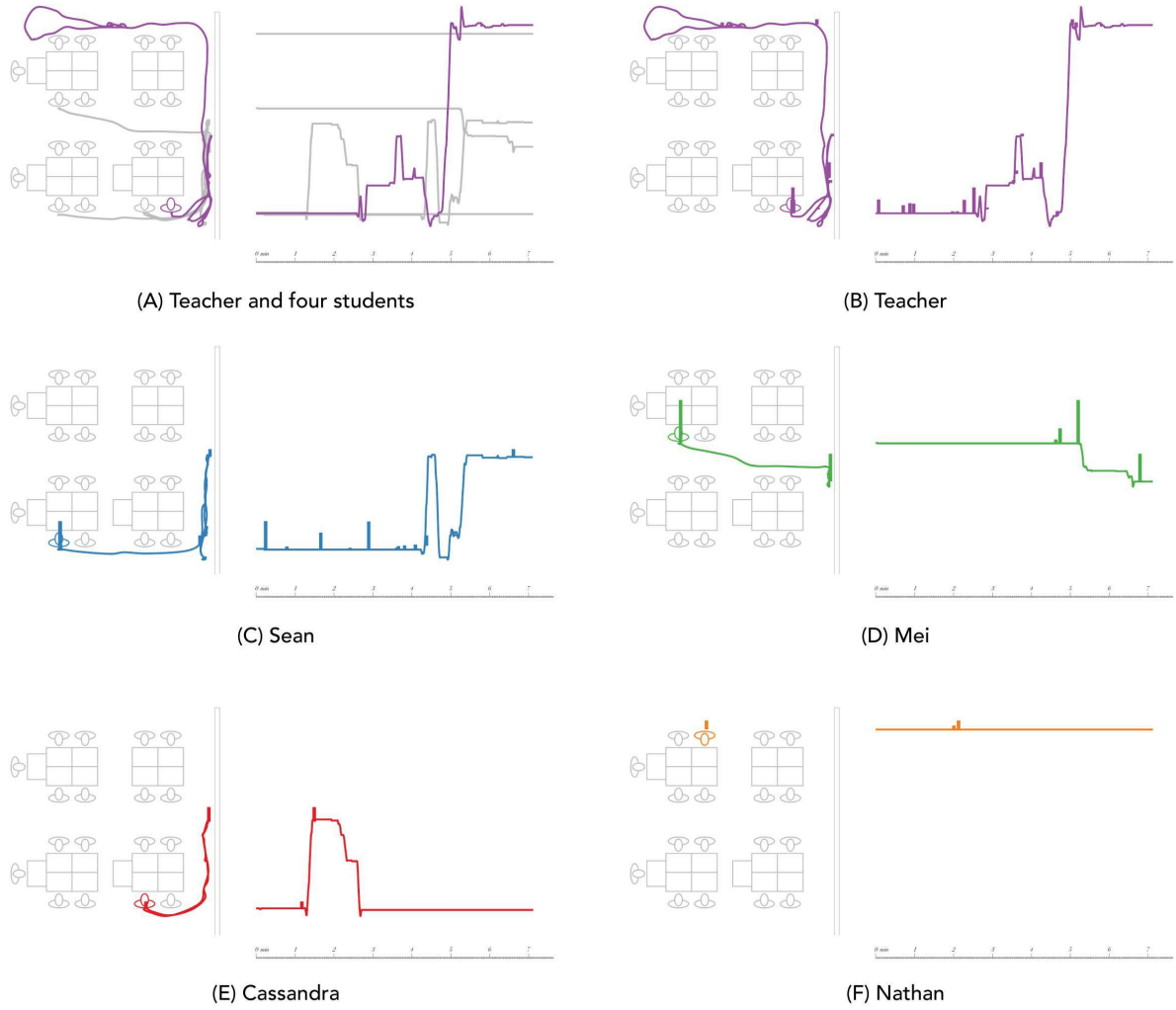

Figure 2. Teacher and student movement and conversation over space and time during a seven-minute sequence of classroom interaction: (A) Teacher (purple) and four students' movement (gray); (B) Teacher movement and conversation, where rectangles indicate conversation turns and the height of each rectangle indicates the length (in words) of each turn; (C-F) Four individual students' movement and conversation. *(Data used with special permission from Mathematics Teaching and Learning to Teach, University of Michigan).*

In comparison to existing work, Figure 2 provides a new type of view of classroom conversation unfolding over space and time. Each image provides a detailed view of an individual's movement and conversation, while the images together provide one type of overview of classroom discourse during this sequence of interaction. These images support rapid comparative analyses between participants in this interaction. For example, the teacher made a number of conversational turns at the beginning of this interaction, but made far fewer utterances after walking across the classroom, as she handed the conversation over to Sean and Mei. Three students — Sean, Mei, and Cassandra — walked to the chalkboard at different points during this sequence of interaction, while Nathan remained at his desk as he made two brief utterances over a period of about 15 seconds. These images provide a way to quickly study and compare individual interaction patterns within a classroom context in ways that highlight particular spaces and moments of potential importance. This, in turn, highlights the need to interact with these representations to more closely study such spaces and moments.

Using the Interaction Geography Slicer (IGS)

Figure 3 is a screenshot from a dynamic visualization tool called the *interaction geography slicer* (IGS). The figure highlights some of the capabilities of this tool, which allows users to dynamically interact with and interpret representations produced through Mondrian Transcription, such as those in Figure 2. Figure 3 shows one of the possible views from the IGS: a teacher-centric view that shows all conversation turns during this sequence, placed

along the teacher's movement path in floor plan and space-time views. Importantly, the IGS allows different ways to view movement and conversation. For example, users could opt to show movement paths from students and to place conversation turns along each participant's movement path; this would more precisely show where and when each student contributed to the conversation.

Figure 3 also illustrates that users can hover over turns of talk to highlight, magnify, and read each utterance. In this case, we have hovered over one particular turn of talk from Sean in the space-time view (at approximately 2:50) to magnify and read Sean's rationale as to why he thinks six is an odd number: "you can split six fairly and you can split six not fairly…" When users hover over an utterance or any part of a movement path like this, a circle appears along the movement paths in both views. In Figure 3, a purple circle is shown along the teacher's movement path in floor plan and space-time views, indicating the teacher's position when Sean made that statement; this allows users to better read both views together. Finally, Figure 3 also begins to show how the IGS allows users to view and interact with video and audio. Clicking the space-time view will activate and play video from this moment of the conversation. Importantly, there are many ways to interact with video and audio through the IGS; we cannot show them all in a static figure. For example, users can quickly rewind, fast forward, and select audio and video by scrubbing or hovering over the space-time view.

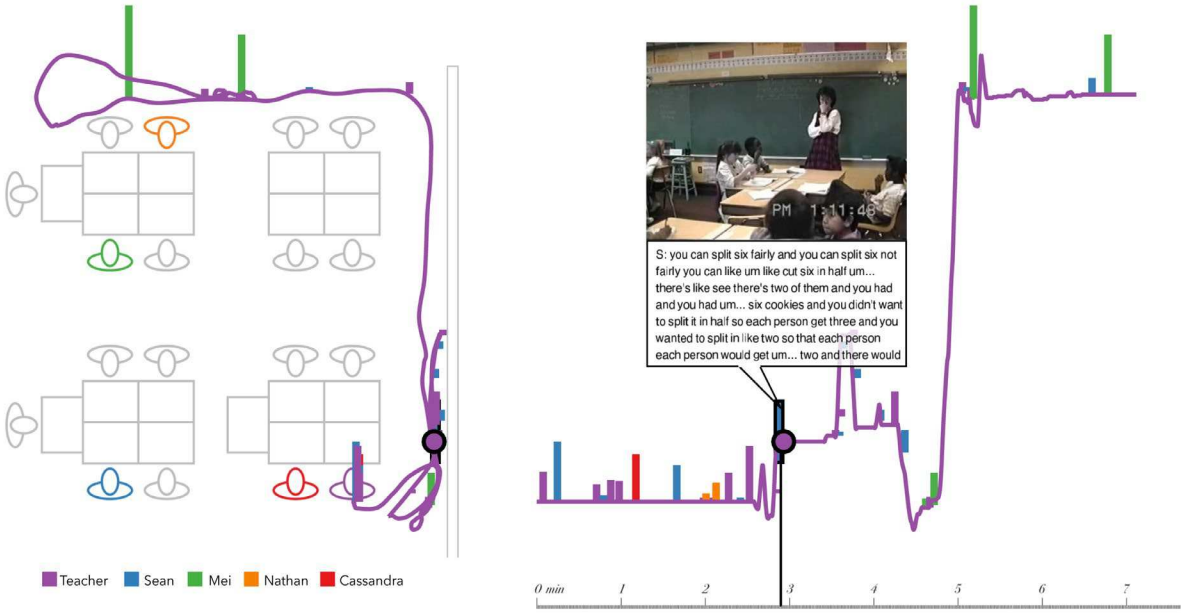

Figure 3. Screenshot from the interaction geography slicer (IGS) showing the teacher's movement, with all classroom conversation placed along the teacher's movement path over space and space-time. The figure also shows how users can dynamically select and read conversation over space and space-time. *(Data used with special permission from Mathematics Teaching and Learning to Teach, University of Michigan).*

The IGS provides an interface to rapidly integrate different types of analyses of participants' discourse (e.g., through audio, video and text) with their movements over space and space-time. On one hand, users can quickly see a selective overview (Ochs, 1979) of classroom discourse over space and time. On the other hand, users can use the IGS to conduct more detailed analyses of moments of interaction and conversation. For example, using the IGS to interact with these data from Ball's classroom allows more rapid and integrative analysis that foregrounds the spatial dimension of how the teacher used movement and conversation over time to take on the perspectives of her students. Namely, the teacher began this sequence of interaction seated at a student desk, taking many turns in the first few minutes of the discussion. These efforts established a conversation space for the class to discuss Sean's reasoning about odd and even numbers. Subsequently, the teacher walked to the chalkboard to invite students into the discussion, and eventually walked across the classroom as she gave the conversation floor to the students, specifically to Mei and Sean. By the end of the interaction shown in Figure 3, the teacher was no longer speaking and remained standing at the opposite end of the classroom from where she started. This gave Mei physical and discursive space to explain her thinking while standing at the chalkboard. Within the IGS, users can read and listen to Mei's explanation while attending to the spatial dynamics of the conversation.

Such interpretive analysis highlights how the IGS can help answer important questions about classroom discourse. For instance, users could examine how the content of students' conversations shifts with respect to the teacher's movement in a classroom (Ehrenfeld & Horn, 2019). Users could also examine participation patterns by analyzing who talks where, when, and how much during a sequence of interaction. More generally, this type of analysis encourages broader questions, such as: How do teachers' use of space over time through movement and conversation simultaneously help a teacher take in multiple perspectives and come to justifiable mathematical (or any disciplinary) decisions? These questions are challenging to ask and answer without space-time views, or in other words, without an understanding of both the spatial and temporal dimensions of classroom discourse.

Discussion

Our analysis here highlights how interaction geography leverages exploratory visualization techniques (Tukey, 1977; Tufte, 1990) to study the spatial dimension of classroom discourse in dynamic visual ways, addressing a methodological gap in the literature. Sean Numbers was selected because of its significance to the teacher education community. However, we suggest that our analysis of this case only begins to illustrate the uses of interaction geography to study complex classroom interactions. This approach offers an important set of methods that stands to contribute to our understanding of the organization of classroom discourse.

Moreover, analyses that are anchored in visual and spatial dimensions of classroom interaction lend themselves to use in teacher education. Though educational researchers and practitioners generally recognize the importance of classroom discourse, there are many different — and often competing — recommendations for "best practices." For instance, we find recommendations that teachers should primarily stand back and listen to students' small-group discussions (e.g., Smith & Stein, 2011) alongside suggestions that teachers frequently intervene to scaffold students' thinking (e.g., Webb et al., 2009). Orchestrating classroom discourse is inevitably complex, as teachers make countless micro-judgments, both intentional and unintentional (Ehrenfeld & Horn, 2019). Through interaction geography, researchers and practitioners can gain a richer view of classroom interaction, including a deeper understanding of the dilemmas teachers face and the choices they make during instruction, as well as the subsequent effects on students' conversation and learning. With that in mind, we are making a data visualization used to produce the figures in this paper freely available for general use by the teacher education community. We hope this visualization can support further development of interaction geography and discussion about the strengths and weaknesses of different pedagogical approaches, while also illustrating new ways to support the professional discourse and reflective practice called for by the teacher education community (e.g., Ball, 1993; Garner et al., 2017; Horn & Kane, 2015; Lampert et al., 2013). We make this visualization available at the following link: https://www.benrydal.com/interactiongeography/classroom

Next steps

As we consider ways to extend the work presented here, there are a variety of promising paths and necessary next steps that we believe are worth consideration for the educational research community. Although interaction geography offers concepts and methods that provide a new perspective on classroom interaction, it remains early in development. With further support and in collaboration with others, we anticipate expanding the set of classroom research applications and scaling up tools such as Mondrian Transcription and the IGS to analyze larger and more diverse data sets in ways that support multiple research traditions (e.g., qualitative or quantitative research). For instance, we expect to customize the interaction techniques and views possible within the IGS to address the needs and goals of teachers and teacher educators, allowing them to pose and explore questions about their instructional contexts through this approach. In creating these customizations, we will consider the types of visualizations that best support teachers' reflective professional practice in a variety of settings. Likewise, these customizations must also address the limitations with conventions used to visualize information as illustrated in this paper. Some of these limitations can be addressed through the visualization of additional data or dynamic interaction within the IGS, but others highlight the limits of exploratory visualization techniques to study classroom discourse.

We also anticipate advances that will allow us to scale up the IGS specifically from being a tool for examining individual classrooms to one that is also able to handle larger-scale data. On one hand, such an effort extends existing qualitative methods of conversation and interaction analysis used in studies of classroom research by providing ways to conduct detailed and integrative analyses of larger amounts of data. On the other hand, such an effort contributes to emerging methods such as multimodal learning analytics (Worsley et al., 2016) to address a long-standing problem in the study of instructional activities. As Rowan, Jacob, and Correnti (2009) observe, efforts to study classroom interaction tend to be time-consuming and expensive, and it is therefore difficult to conduct studies of large numbers of classrooms. We need new methods that have the potential to scale if we are to get beyond limited samples of classrooms.

Furthermore, a critical next step involves deeper theorization regarding what interaction geography illuminates about teacher learning and the situated nature of teaching practice in different types of classrooms. For example, as we begin to scale this approach to allow for comparative analysis across different classroom contexts, we anticipate possibilities to define how teachers' and students' talk and participation patterns shift over varying periods of time and space in new and important ways. Collaborating with others to define and create a taxonomy of such patterns or shifts is an important next step in this work. Finally, collecting data on teacher and student movement, even within the confines of classrooms, should alert us to concerns about privacy (Vincent, 2016), the growth in surveillance in schools (Gilliom & Monahan, 2012), and the need for policies to guide appropriate use of increasingly automated data collection in public and private spaces (Macfadyen et al., 2014). In line with prior work that has used interaction geography as a means to teach data ethics and work closely with professional practitioners (Shapiro et al., 2020), it is critical that interaction geography and any similar methods be used in collaboration with practitioners in ways that benefit students and teachers' work while also recognizing that there will be settings where such approaches are not appropriate.

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