Designing Collaborative Mathematics Activities for Classroom Device Networks

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Abstract: This paper explores the potential of networked devices to support classroom problem solving in small groups. We articulate two principles for designing networked collaborative activities: that they should 1) balance the group's collective engagement of shared objects with opportunities for individual student manipulation of those objects and 2) coordinate networked interactions among student-controlled objects with mathematically meaningful relationships. To illustrate these principles, we present a scenario for small-group collaboration involving classroom device networks.

Introduction

Networks of graphing calculators and handheld computers provide the potential for a range of new structures for classroom collaboration (Roschelle & Pea, 2002). In particular, connections among these linked devices can support networked interactions that complement conventional, face-to-face social transactions in the classroom. Computer-supported collaborative learning often takes one of two forms. In the first, participants engage one another at a distance, *through* the computer, such that the network serves as a substitute for or an alternative to collocated interaction. In the second, participants engage one another *around* a computer, such that the technology complements collocated interaction by providing a medium for coordinating words, gestures, or expressions. Classroom mobile device networks offer distinctive possibilities for simultaneously capitalizing on both of these collaborative modes; our work seeks to develop and explore that potential.

Classroom networks typically feature two interfaces: those available to individual students through their respective devices, and that of a server machine available for collective engagement through a projected display. Similarly, many classroom network architectures are organized around exchanges of information from student devices to a teacher's server and the reverse, rather than between student devices. Each of these constraints poses significant challenges for the design of collaborative activities among small groups of students within a whole-class network. This paper explores network topologies and task designs that address these challenges in order to fulfill what we see as the collaborative promise of networked devices. To that end, we identify two key principles in the design of collaborative activities for classroom networks, and then describe a prototype design representing our efforts to enact those principles. The first of these principles involves balancing a tension between providing students with individual engagement of mathematical objects, and sharing control of those objects across the linked devices of multiple students in a group. The second principle emphasizes our interest in using important relationships among relevant mathematical objects as frameworks around which to organize corresponding networked transactions among devices, and collaborative interactions among students. These principles are elaborated in turn below.

Coordinated Control of Collective Objects

Our approach to conceptualizing small group collaboration is compatible with that of Roschelle and Teasley (1995), who define collaboration in terms of participants' ongoing efforts "to construct and maintain a shared conception of a problem." In that regard, we seek to develop problem-solving tasks around students' engagement with collective mathematical objects. Such objects are collective to the extent that they can be simultaneously examined and jointly manipulated by multiple participants. The objects of interest in this paper are mathematical phenomena such as functions, expressions, coordinates, shapes, or sets. We take such objects to be collective when they or their attributes appear—and change—simultaneously on the devices of multiple students, or when they appear in a shared display as a consequence of contributions from multiple students. Control of such objects might take the form of, for example, entering an algebraic expression, adjusting a parameter, translating a graph, editing a table, or moving a point. The issue of shared control, then, concerns the ways and the extent to which such object manipulations are conducted jointly. Does one student take responsibility for editing an algebraic expression while the others consult? Or does each student edit a parameter of a shared expression? Or does each student enter and alter her own expression? Personal devices can provide each student with the capacity to make independent contributions to networked collaborative activity. While this capacity affords rich opportunities for the participation and engagement of all students in a group, it also necessitates careful management of those contributions in order to ensure that they lead to productive collaboration.

Mathematically Meaningful Links

The second key element of our approach involves designing activities and problem-solving situations in which networked social relationships among students are aligned with mathematical relationships. In particular, both the ways control of objects is shared among students, and the ways resources and responsibilities are distributed among students, are organized so as to reflect important links among mathematical phenomena. This principle is closely related to Stroup, Ares & Hurford's (2005) notion of mathematics structuring social activity in networked classrooms. Because our designs target small groups of two to four students, they emphasize mathematical relationships of similar scale. The scenario presented in this paper, for example, highlights the unique linear relation specified by two distinct points in a Cartesian plane. Our collaborative activities are organized around network topologies that are based on this mathematical relationship, so that a student group might be defined by the network in terms of the curve specified by the set of points through which it must pass, each of which is controlled by a different student. The instructional goal of linking mathematical and social interactions in this way is to use the connections among students to make salient the corresponding connections among the representations and objects those students respectively observe and control—recognition and understanding of those mathematical relationships is a central learning objective for these designs.

Group-Level Graphing: Relating Points and Curves

This scenario uses the NetLogo modeling environment (Wilensky, 1999) and HubNet network tools (Wilensky & Stroup, 1999) in concert with the TI-Navigator 3.0™ graphing calculator network to situate collective objects shared by small groups in a public classroom display shared by the whole class. In this design, teams of two students jointly manipulate points and curves in a coordinate graph assigned to their group. A single machine projected at the front of the room functions as a server and a collective display for up to twelve groups. Figure 1 shows the respective graphing calculator screens and coordinate locations for a pair of students collaborating in a "Lines" activity, and Figure 2 shows their collective graph as it appear in the public display. Each student in this pair uses arrow keys on her calculator to control the location of a point displayed both on the personal device and in the shared graphing window. That student's point is paired with that of a partner so that the coordinates of their points collectively define a line. As each student moves the individual point controlled by her device, the collective display dynamically updates both the algebraic equation and the graph of the resulting linear function even as it is continually transformed by students' position changes. Students are asked to perform a variety of tasks in this setting, such as generating a new line that maintains the same y-intercept but features a specified new slope, or maintains the slope while adjusting the intercept. In order to complete these tasks, students must explore the relationships between their respective points and the shared curve as they learn to coordinate their movements toward the desired transformations. The "Lines" activity also allows two pairs of students to share the same graph (Figure 2). This enables each pair of students to collaborate within the pair but also enables interaction with the other pair on the same grid. By undertaking tasks involving generating parallel, perpendicular, intersecting or other relationships among these lines, students must coordinate their efforts with one another within and between pairs as they negotiate a complex set of relationships among points, and among the curves those points define.

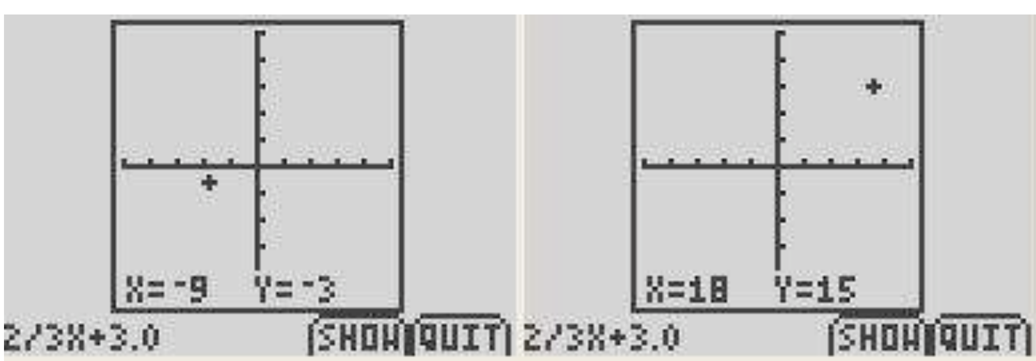

Figure 1. Two student calculator screens in the "Lines" activity.

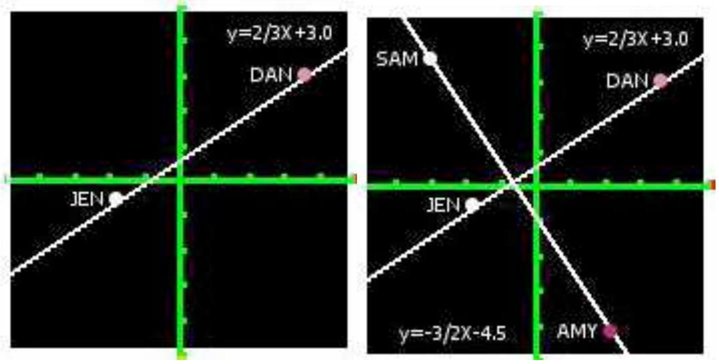

Figure 2. One and two student pairs in publicly displayed graphs.

The "Lines" activity illustrates our principles regarding both coordinated control and mathematical links. In each of these tasks, students control both an individual object, in the form of their respective points, and a collective object in the form of a line. While each student freely moves a distinct point, moving the line in accordance with various tasks requires two students to carefully coordinate those individual movements. Moreover, the relationship between these two students follows from the mathematical relationship through which two points in a coordinate plane uniquely determine a line. In the activities for two pairs of students and their respective lines, the social interactions among pairs correspond to a second level of mathematical relationships, namely among the linear functions generated by each pairs' set of points. In each case, the tasks require students to reconcile their networked interactions with relevant mathematical relationships among the objects they manipulate.

Conclusion

The collaborative scenario presented in this paper represents one approach to negotiating the tension between collective ownership and individual control of mathematical objects, and to linking social and mathematical relationships in a problem-solving space. Different scenarios invariably enact these principles in different ways; we see the example presented here as a starting point toward exploration of a much broader range of collaborative possibilities opened up by classroom device networks. These two principles are by no means comprehensive with regard to collaborative designs in these connected classroom settings. Rather, they reflect themes that have been particularly salient in our initial implementation efforts and instructive in our designs to date. We expect that our continuing efforts to implement these networked problem-solving activities, and to design additional collaborative scenarios, will allow us to further expand and elaborate these principles even as we derive empirical insights into the nature and the effectiveness of the learning opportunities they provide.

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