Educational Communications and Technology:
Issues and Innovations

Laurie O. Campbell
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Ronald F. DeMara *Editors*

Perspectives on Digitally-Mediated Team Learning

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Preface

As information continues expanding and occupational knowledge becomes increasingly specialized, the ability to work effectively on diverse teams becomes increasingly vital. The trend towards more robust collaboration, knowledge management, and communication skills is an increasingly central skill for today's students who will become tomorrow's workers in STEM fields. Thus, providing learners with teamwork, collaboration, communication, and problem-solving opportunities across diverse disciplines is becoming a more necessary, but often overlooked, aspect of education in a variety of fields. Further complicating this issue is that such skills are not typically developed via traditional instructional practices. One potential manner to simultaneously address these issues is through revisioning pedagogical practices, transitioning from more passive, teacher-centered to more active, collaborative, student-centered instructional approaches. Considering the unprecedented emphasis on education, both nationally and globally, the ever-escalating needs and the broad implications of establishing research-based evidence and guidelines for promoting innovative pedagogical practices that support team-based learning are increasingly critical to achieve success.

Solving multifaceted problems to address societal concerns supports the need to build teams that can solve complex issues. In that vein, various disciplines can support team dynamics through digitally mediated team learning (DMTL). DMTL is positioned within known bodies of learning science literature including but not limited to: (a) Computer-Supported Collaborative Learning (CSCL), (b) Computer-Mediated Communication (CMC), (c) Team-Based Learning (TBL), (d) Case-Based Collaborative Learning (CBCL), (e) Collaborative Learning (CL), (f) Cooperative Learning (CopL), (g) Problem-Based Learning (PBL), (h) Learning Analytics (LA), and (i) Educational Data Mining (EDM). Further, DMTL embraces technological applications that afford learners opportunities to solve problems, develop ideas, and co-construct learning outcomes, either asynchronously and synchronously, whether students are in the same room or across the world, providing for ease of communication, documentation of process, and co-construction of solutions and idea.

DMTL-focused pedagogical approaches can leverage advancing learning technologies toward attaining great potential to increase educational efficacy, scalability, and diversity across fields and levels. The activities that support team design, group problem solving, and project collaboration have always been a prominent and even defining attribute of effective pedagogy. Especially in the last two decades and into the foreseeable future, team design skills are receiving increasing importance as the complexity of knowledge acquisition, retention, and transfer marches ever forward. The rising tide of complexity necessitates future graduates at all levels and across numerous fields to function effectively as disciplinary specialists who work together closely and frequently during most phases of product development and research. The need and benefit for learners to become immersed in collaborative learning activities have been highlighted, in order to elevate their needed proficiency in team-based skills. Thus, the priority for advancing forward-looking educational technologies demonstrating the most significant potential to advance team-based instruction is vital and broadly impacting across fields as learning partners, group project teams, and collaborative design projects rely heavily on team-based and collaborative learning. Research in DMTL is especially timely due to the recent proliferation of virtual collaboration technologies ranging from laptops and other mobile devices, tablets, Wi-Fi-enabled networking, sensors, cameras, and embedded devices.

This book emerged as a response to the need to support transactional communication leading to transformative learning and, more specifically, the National Science Foundation *Principles for the Design of Digital Science, Technology, Engineering, and Mathematics (STEM) Learning Environments* awarded grant [DCL-NSF 18-017], grant DRL-1825007 titled *Synthesis and Design Workshop: Digitally-Mediated Team Learning* resulted from a collaborative effort of the editors to address these emerging pedagogical needs. The workshop that took place during the spring of 2019, at the University of Central Florida included 88 researchers, educators, and practitioners from across the United States. Participants explored effective and scalable team-based learning in digital environments and projected how varying aspects of the field would morph and grow in the subsequent 1, 3, and 5 years. Out of a desire to highlight current work in the field of those practicing aspects of DMTL, the creation of this book was initiated. Thus, this book will explore technology-supported pedagogical approaches that facilitate teamwork, collaboration, communication, and problem-solving opportunities in diverse disciplines and is motivated by expanding the learning science research base regarding how constructivist pedagogical principles and strategies, including structured, collaborative, active, contextual, and engaging instructional settings, can support foundational instruction and improve student interest and achievement.

This book showcases full-length manuscripts advancing transformative pedagogical approaches for technology-enhanced team learning within varied disciplines and includes contributions from interdisciplinary researchers, developers, and educators focused on the facilitation of adaptable digital environments for highly effective, rewarding, and scalable team-based and collaborative learning. More specifically, this book highlights theoretical works and empirical studies that explore ways in which technology-enabled pedagogical principles and practices facilitate student interest, while also providing an exploration of logistical factors associated with revisioning pedagogical approaches and informing the design of instructional settings in various subject areas in K-12 and higher education. Further, these works will assist administrators, instructors, and course developers in creating effective learning environments to best meet the needs of all students, while simultaneously addressing technology-supported pedagogical and logistical challenges commonly seen in K-12 and higher education.

Book Sections

At its core, this book is focused on advancing knowledge on technology-enabled team and collaborative learning. The chapters within will inform immediate and future research and practice related to: (a) harnessing learning analytics for optimal team learning; (b) innovative pedagogical approaches utilizing technology-enabled team and collaborative learning; (c) traditional and emerging technological applications to support and promote team-based learning; and (d) logistical and other issues for broadening participation and presence in team learning. The explorations and outcomes related to these topics are of interest to researchers, educators, and industry as they could inform the creation of beneficial, scalable, sustainable, and transportable educational solutions for developing team learning and interactive learning environments through digital means. This book contributes to future cross-networking and co-constructing among the experts in the aforementioned fields as they continue to investigate aspects of digitally mediated team development to benefit the associated researchers, educators, and practitioners.

The book is structured around the following parts:

1. **Pedagogical Perspectives in Digitally Mediated Team Learning**
   The ability to facilitate DMTL-focused approaches across levels and disciplines is becoming increasingly important. While technological tools that support varied pedagogical practices that enable effective DMTL-focused teaching and learning environments are becoming increasingly common and useful, it is critical that such tools be accompanied by appropriate pedagogical approaches that address the myriad of issues associated with effectively facilitating DTML-based environments and support such approaches as team design, group problem solving, and project collaboration. The four chapters in this part explore various aspects of DMTL-rich teaching and learning environments by highlighting instructional approaches to address a variety of pedagogical issues typically associated with team learning, such as (a) instructor roles in real-time team-based instructional settings, (b) managing accountability in team-based settings, (c) aligning tools with appropriate pedagogical approaches, and (d) team-based learning at various educational levels, among others.
2. **Tools for Facilitating Digitally Mediated Team Learning**
   The increasing ubiquity of technology in almost every aspect of our everyday lives as well as the continually increasing usability and advanced functionality of

both traditional and emerging technologies opens the doors for a myriad of approaches to the numerous pedagogical, logistical, and social issues associated with team-based and collaborative learning. However, the integration of these tools into the teaching and learning environment is not one of merely "plug-and-play." Thus, in this part, the three chapters provide guidance for the integration of traditional and emerging technological applications and address a number of ways in which such tools can allow for more active, engaging, and communicative teaching and team-based learning environments, as well as ways in which tools can support instructor professional development for the integration of both traditional and emerging technological tools to support DMTL-based pedagogical approaches in STEM curricula.

3. **Analytics and Social Perspectives of Digitally Mediated Team Learning**
   Research regarding the formation and function of teams continues to grow in the teaching and learning literature. Learning analytics provide rich information for making informed decisions regarding learning. In technology-mediated environments, analytics can support understanding for instructors and team members of how teams are functioning. The data points generated in learning may optimize the individual and team learning experience. Likewise, social presence, a construct that has evolved to mean the way individuals view social interactions and others, has been identified as a contributor to learner satisfaction, performance, and achievement. In this part, social presence has been explored to include definitions, tools, and actions that will build rapport and trust among learners in online environments.

In conclusion, we are pleased to be able to bring you this book on a variety of issues associated with DMTL. In these pages, you will find thoughtful and well-written chapters that can be used to improve practice while informing both current and future research.

Respectfully,

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Contents

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Part I
Pedagogical Perspectives in Digitally-Mediated Team Learning

Aligning Teacher Facilitation Tools with Pedagogies in a Real-Time Environment for Mathematics Team Learning

Leslie Bondaryk and Chad Dorsey

Abstract Digitally facilitated team-based classrooms require a rich set of tools to support teacher noticing and classroom orchestration. While only limited research has been conducted on effective tools for teachers, we have been able to construct a teacher dashboard along with feedback and content customization features that allow middle-school mathematics teachers to effectively teach team-organized, digitally facilitated classes in an in-person, hybrid, or online classroom environment. Two key features of the digital environment include a dashboard allowing the instructor to monitor and inspect all student artifacts in real time and a workspace allowing teachers to generate and publish content of their own. We describe the functionality of the purpose-built STEM collaborative classroom system and the particular ways it facilitates effective classroom orchestration and noticing.

Teaching with Technology-Enabled, Problem-Based Curricula

Teaching a technology-enabled, problem-based curriculum is a balancing act between keen student observation, prompt just-in-time contextual problem feedback, and technical support of the software platform. Teachers need to aid students in acquiring facility not only with the content and practices of the domain but also with the mediating technology-based tools. In such a scenario, teachers and students share more responsibility for the learning process than in a teacher-centered or direct instruction environment (Bransford et al., 1999; Lampert, 2001). Teachers in software-enabled scenarios assume an increased burden to notice and evolve the disciplinary content of students' work (Franke et al., 2001; Schifter, 2005). Student work in teams within a platform magnifies this challenge, as the flow of ideas between students and the path along which the group work evolves is part of the work of constructing the team's joint problem space (Roschelle & Teasley, 1995;

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Stahl, 2006) and demand teacher coaching and evaluation. In live classrooms unmediated by digital technology, much of this interaction is ephemeral, lost to untracked conversations, or locked in individual students' notebooks. In other cases, the interactions veer off-topic entirely (Barron, 2003). Effective teacher noticing depends strongly on teacher access to student inscriptions (Sherin et al., 2011). Thus, supporting such noticing in technology-based scenarios, where the majority of students' work occurs on screens, demands new types of digital support features (Walkoe et al., 2017).

Classroom Orchestration

Teachers in a hybrid or purely digital setting depend broadly on digital systems for access to facets of learners' activity that stretch beyond basic measures of progress. A digital platform tool must be capable of communicating the class "script" to the students and must allow the teacher to track progress against that script (Martinez-Maldonado et al., 2015). Teachers must be able to see and comment on their students' learning artifacts in ways that are easily consumable by students. They must also have access to both synchronous and asynchronous methods of communication with multiple class members such that they can provide clear written expectations and responses across reliable sequences of activity, discussion, and reflection (Amarasinghe et al., 2020; Tinker, 2001).

Teachers should be able to communicate effectively in the subject matter domain in written form, including through digital means. Preferably, this communication should employ an identical inscriptional toolset to that used by students, to allow for equivalent abilities to facilitate and communicate about the content. In a collaborative classroom, teachers need to monitor the progress of both individual students and groups. Additionally, teachers need classroom orchestration tools that can help them understand the progress of the class as a whole so they can efficiently identify commonalities in student understanding, customize curriculum, and moderate group dynamics (Dillenbourg et al., 2012; Matuk et al., 2015). A classroom system for mediating collaborative learning should help teachers to orchestrate learning, including summaries of class understanding, and to conduct group facilitation activities. Protocols for these activities in the physical classroom often have well-established, paper-based patterns. However, they may or may not occur identically in the digitally mediated classroom. Finally, these digital tools must support instructors in evaluating students' overall progress and in assessing how the curriculum materials, digital platform, and student interactions support or hinder the progress of individuals, teams, and the full class.

In order to facilitate a documented trail of student inscriptions that benefit both student learning and teacher noticing, the Concord Consortium has developed a collaborative mathematics platform that allows students to work with digital mathematics tools in groups. The Collaborative Learner User Environment (CLUE) is designed to provide the curriculum (Dillenbourg et al., 2012 "script"), the student artifacts, and the teacher commentary all in the same format via the same digital tools. This set of common affordances allows students to observe, publish, and borrow artifacts directly from shared peer work, instructor-provided materials and exemplars, and the curriculum materials themselves (Dorsey & Bondaryk, 2019; Sharma & Edson, 2020). While the system is an equalizer in the classroom, encouraging all students to participate and validate their contributions among their peers (Sharma & Edson, 2020), teaching with this real-time collaborative document system presents a number of unique challenges. We designed a set of platform affordances that support teacher noticing and interaction with individuals, groups, and the whole class, teacher evaluation of work, and teacher participation in the collective process. The platform offers an unprecedented window into how groups of learners generate, borrow, amend, and share artifacts in a learning environment in which the goal is to collectively discover, define, and refine mathematical principles. This information is invaluable to teachers seeking to scaffold their students. The dense, rich nature of possible feedback requires specific affordances to allow teachers to make sense of student inscriptions and interactions and capitalize on them for the benefit of problem-based instructional techniques.

Classroom Script and Monitoring

To date, classes using this platform have been taught in the context of the *Connected Mathematics Project* (CMP) curriculum (Lappan et al,. 1998, 2006, 2014). This curriculum was originally designed for paper and pencil in a live classroom. Instructors both participate in and assess success in the paper curriculum through observation of physical group documents and individual student notebooks of mathematical inscriptions. Within the digital system, we needed to provide equivalent or enhanced opportunities for the same type and quality of interactions. Further, in the digital system, inscriptions are copied from one student's document to another to evolve ideas, allow students to see tangible artifacts and evidence that their ideas are valued by their peers, and enhance the collective understanding. Teachers can capitalize on this to follow and encourage the temporal joint problem space evolution (Sarmiento-Klapper, 2009), providing benefits to both the students and the teacher (Edson & The Concord Consortium, 2019).

The CMP problem-based curriculum is a good test of the CLUE Platform's collaborative teacher supports because of both the consistency of the program's curricular sequence within each unit and the rigorous teacher training that is part of the program. These commonalities allow us to return information to teachers via a dashboard in a consistent—and, therefore, learnable—format. Teachers of this curriculum are active participants in the evolution of ideas in groups, actively responding to individual- and group-developed concepts and evolving classroom learning needs. They must introduce problem-based activities while connecting them to previous learning and must continually track and advance work across the classroom. During class and teacher preparation sessions, teachers must be able to review student work while preparing for unit summaries or setting up instruction for the following day or beyond. During this review teachers identify student exemplars that may be useful for group conversation and search for concepts taken up and/or missed by individuals, groups, or the entire class. At regular intervals, teachers must orchestrate whole-class summary discussions in which they draw examples from student strategies and group work, sequencing them to evoke the embedded mathematical understandings and elicit group realizations about how these understandings connect the work together and tie it to both prior and future knowledge (Bieda et al., 2020).

Student Experience and Workflow

To understand the teacher affordances in the mathematical platform, it is first important to understand the student experience inside the team-based learning environment. The system groups students in teams of up to four students. Students have access to a variety of domain-appropriate tools (e.g., graphs, tables, text, images, and drawings), which they can use in ad hoc and self-selected ways. A series of "tiles" that the student can freely rearrange, update, and delete in their documents contain tools for writing text, manipulating geometric figures, creating graphs, and more. Students construct documents in CLUE using these tools to create responses to questions posed by the teacher and the curriculum materials. The CMP curriculum is built into the platform, and the published content uses the same set of platform tools. This pattern enables students to copy items directly from the curriculum to incorporate into responses. The ability to begin with content that can be freely transformed by students, in tandem with the team-oriented and open-ended nature of the problems themselves, deliberately creates opportunities for individual students or groups to arrive at alternative approaches to problem solutions.

Class work typically follows a pattern that involves members working individually, followed by a reveal of individual work to group members, and then to the whole class, although some teachers prefer to have groups begin with student workspaces immediately shared within groups; the platform supports either approach. Documents allow students to copy granular pieces from each other's work or from the curriculum by dragging and dropping tiles or subsets of content, a feature designed to encourage cross-pollination of solutions and ideas. The overall effect of this interaction pattern is to elevate student contributions to an equivalent level of importance to those from the original problem. Studies of the Scratch community show that users can learn by looking at and borrowing from other users' creations (Resnick et al., 2009). In those cases, however, the interactions are typically unidirectional, with feedback tending to consist of the "giving of credit" to originators of the source project (Monroy-Hernández & Hill, 2010). In contrast, we designed the CLUE interface explicitly to encourage learners to model for one another and learn from one another, using an always-available WYSIWIS (Stefik et al., 1987) shared desktop and structured intermediate work products designed to promote iterative refinement (Dorsey & Bondaryk, 2019).

This work pattern also helps students overcome confusion over how to begin a problem, especially in classrooms where the culture and social contract acclimate students to holding each other accountable for the overall classroom learning and for contribution to equal shares of the assignment work. Once students have achieved some success in their groups, teachers sometimes encourage students to publish their work so it can be viewed by the whole class. Each of these real-time document instances, whether shared within small groups or across the full class, have the same "borrow-and-reuse" functionality. Students are also encouraged to journal in a "learning log," another set of cross-referenced documents that sport the same toolset but are available persistently across curriculum units, encouraging students to build upon previous solutions and reflect on their learning over time. Such documents eventually even become founts of information for students, which they can use to "borrow from themselves" to construct summaries of understanding or bridge to new work from past understandings.

One of the interesting opportunities this pattern of progressive refinement affords is the opportunity for students to do the same kind of peer instruction previously instrumented with clicker systems. In such clicker systems, students typically answer a question individually, discuss the question with their peers, and answer the question a second time as a group (Barth-Cohen et al., 2016; Mazur, 1997). A prime value such systems offer instructors is the manner in which they provide real-time recorded feedback about student understanding and reveal its progressive evolution. In similar ways, the CLUE collaborative platform can provide invaluable, ongoing monitoring of peer inscriptional evolution and student understanding.

Affordances for Class Orchestration

Teacher Dashboard

To facilitate monitoring of this dynamic, multi-team system, we needed to create a robust set of teacher tools that would enable teachers to keep pace with the fast-moving groups of students as they swapped and shared ideas and inscriptions that offered benefits above and beyond what could be done by walking around a classroom with students working on paper. While a number of projects have created classroom dashboards to monitor students' individual learning progress (Verbert et al., 2013), very few allow teachers to monitor the state of collaboration within small groups (Martinez-Maldonado et al., 2012) or with a sophisticated set of STEM-based live artifacts. The platform described here includes a teacher dashboard that specifically supports monitoring of progress on the CMP curricular sequence and provides actionable insight and an interface to digitally conduct the orchestration required by the curriculum.

For teachers beginning a particular problem in the curriculum, the starting point is their teacher dashboard, a display that shows all student documents depicted in their group formations (Fig. 1). For reasons of screen real estate, we have limited the view to six groups of four students each; in classes with more than six groups, teachers can access additional groups by scrolling the screen downwards or upwards.

This view supports a rich set of observations. The nature of the mathematical content, particularly in a seventh-grade mathematics curriculum unit focused heavily on geometric transformations and linear data manipulation, makes it very easy for a teacher to tell which students are progressing predictably on a given problem and which are pursuing alternate or off-topic solution paths, even using these thumbnail-sized views of the student artifacts. For example, the problem shown in Fig. 1 involves shapes that tile into similar larger versions of themselves. (Student work from Group 3 in the upper right corner and Groups 4 and 5 on the lower row shows a set of shapes supplied with the curriculum.) Some students have only progressed as far as copying the supplied set from the curriculum, while others have used these shapes, or some of their own, to create tiled fields of shapes within their graphs. Some have not started (evidenced by documents displaying only horizontal document separator bars as in Groups 2 and 3). Several students are documenting their work (text areas) and one student is absent (the white square in Group 5).

This dashboard view also allows teachers to determine the progress of students within each problem itself. The circle icons on the far right indicate the typical sections in this curriculum. Next to each section icon is a count of the number of students who have entered at least one content tile of any sort in that section.

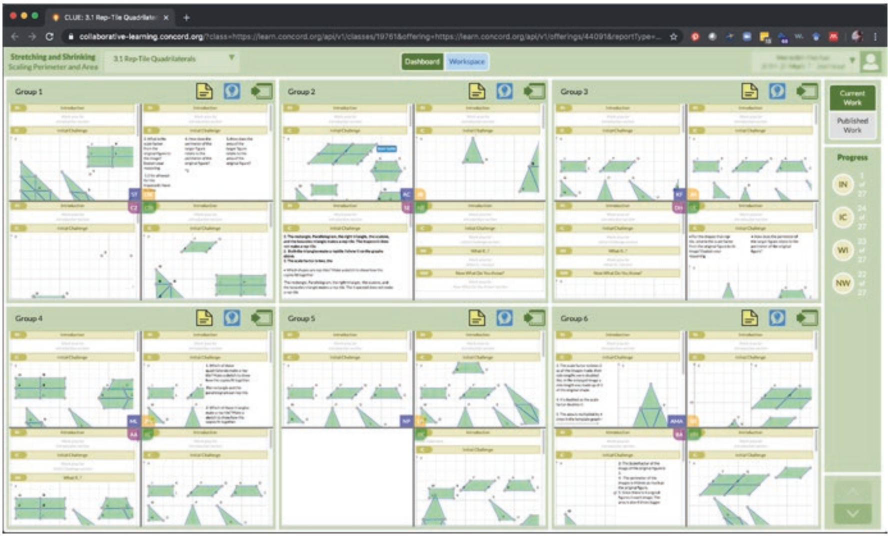

Fig. 1 The Collaborative Learner User Environment Dashboard, showing 24 real-time student documents in progress and teacher intervention tools

Clicking on these icons scrolls all student documents to that section, allowing the teacher to compare like parts of the assignment and determine when it is time to intervene, gather students for discussion, or encourage the class to continue to the next section. This functionality offers particular value both for teachers preparing for in-person class sections and for teachers teaching remotely, since remote or asynchronous scenarios often make it difficult to determine when a class is ready for discussion or prepared to transition to a new topic.

It is also possible for teachers to see how many of their students have published work to the class. This alternative view represents the final transition of sharing work and allows teachers both to check the completion and sharing of students and to "star" work pieces for easy reference in the future.

If teachers wish to access a more detailed view of an individual student's work, they can click on that student's pane, which expands the selected student's work to fill the group's frame. Additionally, teachers can also switch to a workspace view that mirrors the group view of students, with the addition of a content tab for student workspaces (Fig. 2). This allows teachers the ability to see a very detailed view of each group and to create reference documents by borrowing student content (using the same, copy and paste mechanisms that work for all users in all documents).

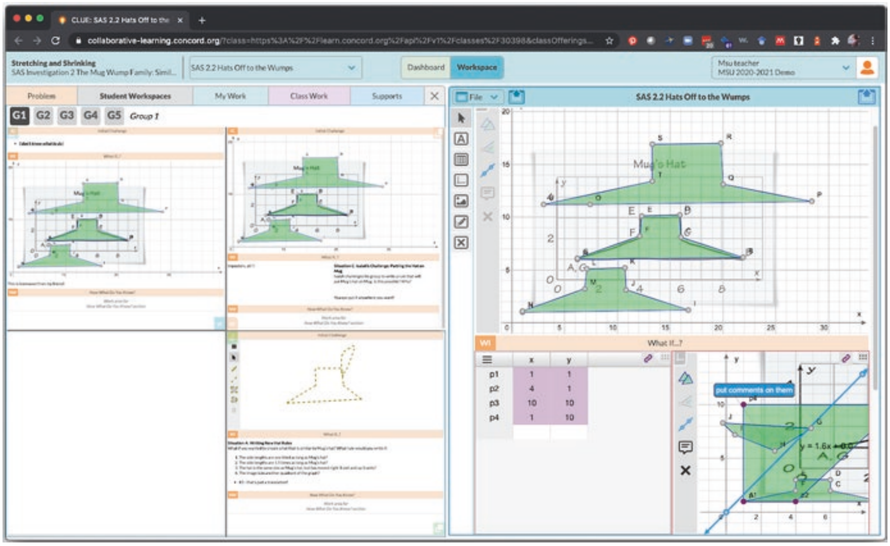

Fig. 2 The teacher workspace has the same functionality as the student workspace (right pane), but also includes a tab in the content section (left pane) displaying the group views of all student workspaces, just as the dashboard does

Teacher Interventions: Notes

Teachers using the CLUE platform have a variety of options for interacting with their students, all of which speak to the noticing and orchestration themes of collaborative teaching. In the dashboard view, yellow "sticky note" icons are associated with each group. These allow the teacher to instantly send a note either to the whole group or to an individual student. Annotations persist in the student workspaces (Fig. 3) and can be used for anything from motivational feedback to classroom prompts. One teacher in a spring 2020 class test used these to provide slightly different question prompts to each student in each group. As students worked on the individualized prompts, then shared their work with their group mates, they discovered that each was working on a slightly different form of a related problem, evoking a more nuanced group conversation and interaction about the nature of the problem and comparison of alternate solutions.

Among the 5 teachers in 23 classrooms who participated in trials during the spring and fall of 2020, in various in-person, hybrid, and remote learning environments, we saw a broad variety of uses of notes. Some teachers used them to engage students in class participation, or to facilitate turn taking during class-wide discussions. For example:

- "Raise your left hand when you see this!"
- "Group 21!!!!! It's finally your turn!!! Hiiiiiii!!!!! :-)"
- Other teachers included motivational feedback to students:

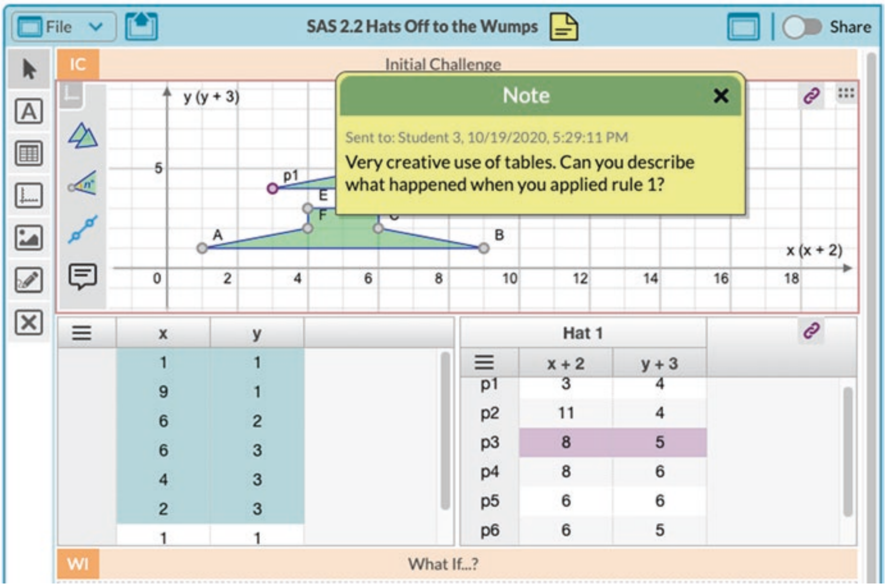

Fig. 3 Sticky note display for teacher-to-student commenting and feedback