

LESSONS LEARNED FOR DEVELOPING AND ENACTING A DIGITAL COLLABORATIVE PLATFORM WITH AN EMBEDDED PROBLEM-BASED MATHEMATICS CURRICULUM

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In this chapter I report on a design research project of a digital collaborative platform for an embedded problem-based mathematics curriculum—the Connected Mathematics Project (CMP). The goal of the project is to enhance the teaching and learning of mathematics that occurs in paper-and-pencil classrooms by leveraging the affordances of digital technologies in a digital classroom environment. In this chapter I share lessons learned for developing the digital collaborative platform for students and teachers, focusing on how the project team: (1) reimagined mathematics problems delivered in a digital collaborative platform, (2) supported a model of collaboration in the digital platform, and (3) provided students with just-in-time supports in the digital collaborative platform. To illustrate the lessons learned, I report on the iterative changes made to features of the digital collaborative platform based on analysis of project data and feedback from teachers and students.

Keywords: computer-supported collaborative learning; digital environments; mathematics learning and teaching; middle-grades mathematics; problem-based curriculum

INTRODUCTION

The evolution of digital technologies has led to numerous internet-based resources that are accessible to students and teachers. Although many digital resources include lessons and activities, many publishers and education software companies are releasing comprehensive programs, platforms, and systems designed to supplement or supplant print textbooks. These resources present researchers, teachers, and curriculum developers with new affordances for how students and teachers enact mathematics curricula in digital environments. Understanding the extent to which digital resources have the potential to change curriculum enactment compared with conventional classroom environments is critically important to improve the teaching and learning of mathematics.

The set of curriculum materials embedded in the digital collaborative platform discussed in this chapter is the Connected Mathematics Project's middle grades problem-based curriculum, *Connected Mathematics* (CMP) (Lappan et al., 2014; Phillips et al., 2025). Problem-based learning occurs as students “engage a problem without preparatory study and with knowledge insufficient to solve the problem, requiring that they extend existing knowledge and understanding and apply this enhanced understanding to generating a solution” (Wirkala & Kuhn, 2011, p. 1157). The focus on student thinking in problem-based curricula differs from *delivery mechanism* curriculum materials, in which students memorize facts and practice demonstrated procedures in a direct instruction classroom (Choppin et al., 2015; Roth McDuffie et al., 2018).

Three important principles related to the teaching and learning of mathematics underscore the design of the digital platform for CMP. First, at the onset of the project, the platform was intended to enhance (not replace) face-to-face mathematics instruction, particularly student-centered, inquiry-oriented teaching and learning of mathematics. The project team developed student and teacher features that leverage the affordances of digital technologies to amplify or transform paper-and-pencil environments without creating new challenges for students or teachers. In physical classrooms, teachers using the platform typically have desktop computers connected to projection systems and might also have access to a tablet or laptop to use when circulating the classroom. As in paper-and-pencil environments, when using the digital collaborative platform, students continued to work in small groups of two-to-four. Rather than students sharing devices in pairs or triplets, it was important that each student had access to their own laptop connected to the internet. This was to ensure access to student resources in the classroom. Because students worked collaboratively with others using a curriculum, the project team designed the platform for laptops so that screen size could support viewing the

mathematics problem, students' individual work, and the work of others. Not every day was a "digital day." On non-digital days, students could upload photos of their paper-and-pencil work onto the digital platform. Some districts provide students with their own laptops, some teachers borrowed district carts for problems, and some teachers used classroom sets provided by the CMP. During the COVID-19 pandemic, students and teachers used video conference tools for small- and whole-group collaboration. Although development of the digital platform began prior to the pandemic, and minor changes were made to support the pandemic (e.g., a notification system was created to let students know they were connected to the internet), the team did not design features for the platform solely for online or remote learning and teaching of mathematics.

Second, the digital platform for CMP differed from other platforms by its emphasis on student and teacher collaboration around a mathematics curriculum. In problem-based mathematics classrooms like CMP, individual and collaborative learning is operationalized through the *Launch-Explore-Summarize* instructional model in both the print materials and the digital environment (Edson & Phillips, 2021; Lappan et al., 2004). In the *Launch* phase, the context and challenge of a problem situation is introduced to students who make predictions and ask clarifying questions. During the *Explore* phase, students work collaboratively to explore and solve the problem by gathering data, sharing ideas, looking for patterns, making conjectures, developing strategies, and creating arguments to support their reasoning and solutions, while the teacher monitors individual and group strategies and provides questions to guide students' thinking. In the *Summarize* phase, teachers facilitate discussion about the mathematical learning goal(s) of the problem while students share, discuss, and refine their strategies and conjectures, which reveal embedded mathematical understandings in the problem situation and connect to their prior knowledge. Although research suggests that computer-supported collaborative learning has even more prominent effects than traditional small-group work without digital devices (e.g., Jeong & Hmelo-Silver, 2016), our emphasis was strengthening individual and collaborative learning during all three instructional phases.

Third, because students and teachers have different roles in the enacted classroom, the design team streamlined users' experiences so that students and teachers share platform interface and functionality whenever possible. The curriculum problems visually appear the same for both students and teachers, yet teachers have access to additional support features. For example, teachers can access embedded student strategies and answers for each problem, and can access the teacher guide support to plan, enact, and reflect on the mathematics problem, which they can incorporate into their teaching and planning documents. High-level features of the platform for students and teachers are shown in Figure 12.1.

Figure 12.1*High-Level Features of the Digital Collaborative Platform for Students and Teachers*

Student Features	Teacher Features
• Investigate problems using a new CMP STEM (Science, Technology, Engineering, and Mathematics) problem format that is embedded in the platform and supports students as doers, knowers, creators, and communicators of mathematics • Develop mathematics with a variety of tools (e.g., graphs, tables, text, drawing, images) in a safe and collaborative setting • Document, share, refine, publish, curate, and retrieve their work, moving back and forth between individual and shared spaces • Extend learning of mathematics concepts by transforming their work into sharable and retrievable classroom artifacts for future use and reflection in a mathematics learning log	• Access curriculum materials including student text, teacher guide, and problem solutions • Monitor evidence of student thinking from individuals, groups, or the entire class in real-time or after school • Select, highlight, edit, and incorporate individual student work into the class workspace • Create and send “just-in-time” supports to individual, group, and classes of students • Collaborate with teacher colleagues and school coaches to create resources, collaborate in the digital environment, and support each other in planning, teaching, and reflecting

After discussing the development of the digital collaborative platform, in the remainder of this chapter I report on lessons learned while developing a digital collaborative platform embedded within CMP. The design principles focused on (1) reimagining mathematics problems delivered in a digital collaborative platform, (2) supporting a model of collaboration in the digital platform, and (3) providing students with “just-in-time” supports in the digital collaborative platform. For each design principle, I share the context for three features of the digital collaborative platform that were iteratively developed, tested, and refined. To illustrate the lessons learned, I discuss iterative changes made to features of the digital collaborative platform based on analysis of project data and feedback from teachers and students.

THE DEVELOPMENT OF THE DIGITAL COLLABORATIVE PLATFORM

Development of the digital platform is conducted by a research team that is a partnership between Michigan State University and Concord Consortium, and includes people with expertise in educational research, curriculum

development, educational technology, and mathematics education. The overarching methodological approach to the research is similar to the iterative process for design research, such as design studies (e.g., Edelson, 2002), design experiments (e.g., The Design-Based Research Collective, 2003), and developmental research (e.g., Richey et al., 2004). The goal of design research is to:

Use the close study of learning as it unfolds within a naturalistic context that contains theoretically inspired innovations, usually that have passed through multiple iterations, to then develop new theories, artifacts, and practices that can be generalized to other schools and classrooms. (Barab, 2014, p. 151)

To create a digital collaborative platform embedded within the CMP curriculum materials, the team engages in an agile development process through rapid iterative cycles of designing, building, testing, and refining. The development process begins with the design of print problem-based curriculum materials; these are embedded into a digital collaborative platform for students; and soon thereafter, the team focuses on features in the platform for teachers that are linked to the student platform. The team uses conjecture mapping for each development phase (Sandoval, 2014). *Conjecture mapping* is a mechanism that makes explicit the relationships between the design of the platform, the enacted experiences within classrooms, and the outcomes associated with those experiences. The classroom testing is conducted with experienced mathematics teachers using the CMP curriculum materials from school districts in the midwestern and northeastern U.S. Because teachers enact seventh-grade CMP units at different times throughout the year, the team engages in multiple iterative cycles per year.

LESSON ONE: REIMAGING MATHEMATICS PROBLEMS FOR THE DIGITAL COLLABORATIVE PLATFORM

The first lesson focuses on connecting the mathematics problem with the student and teacher workspaces. In many classrooms, textbooks have been supplanted by consumable workbooks and internet-downloadable worksheets (Rohrer et al., 2020; Umriani et al., 2020). The design and format of written tasks are variable, as outlined in the following contrasts:

- Do the written tasks come across as blanks to fill in, or do they invite students to explore and solve problems involving important mathematics?

- Does the structure of tasks help provoke and develop student thinking over time, or do they support a model where students memorize facts and practice demonstrated procedures?
- Does the structure offer an assumption that subsequent work is based on problems of the same kind, or do students need to consider ways in which subsequent questions relate to each other?

The design of written tasks and their format is important for studying students' opportunities to learn mathematics and how they are taken up in classrooms by students and their teacher.

To enhance the teaching and learning of mathematics, the project team considered the task design and structure of the written mathematics problem. The team recognized that current written tasks—either those oriented toward student thinking or delivery mechanism—are structured around a conventional linear format (e.g., A1, A2, B1, B2, B3). Three considerations were critical in reimagining the task design and structure: (a) the research design work that went into prior versions of the print CMP materials (Edson et al., 2019); (b) new possibilities for how students (and their teachers) engage in and learn mathematics (Edson, 2016, 2017); and (3) the resources needed to support teachers' classroom practice.

Platform Design Feature: The CMP STEM Problem Format

The CMP STEM Problem format resembles the work that STEM professionals do to solve problems, build deep knowledge and skills, and meaningfully connect these solutions to inform the needs of society. The CMP STEM Problem feature consists of three connected components of the task structure: (1) *Initial Challenge*, which poses the mathematical challenge and provides open access for students in terms of access points, possible strategies, and nature of solutions; (2) *What If...?*, which unpacks the mathematical understandings and where students probe deeper at the mathematics by considering different situations when you change quantities, contexts, or strategies; and (3) *Now What Do You Know?*, which connects prior and future knowledge so students can self-assess and consolidate their learning of mathematics. For students, the task design promotes student engagement and learning as they collaborate to design solutions, make conjectures, offer critiques, and communicate their mathematical understandings. For teachers, the task design is more explicit in terms of the goals for mathematics problems, namely to (a) attend to the strategies students use to solve problems, (b) help students recognize the embedded or encoded mathematical understandings, and (c) connect these understandings to prior and future knowledge (Edson et al., 2019).

Figure 12.2 shows an example of the unit *Stretching and Shrinking: Developing Proportional Reasoning in the Context of Similarity (Scale Drawings)*. In this problem, students investigate the effects that various algebraic rules have on a hat for Mug. In the *Initial Challenge*, students explore what happens to the location of a hat when numbers are added to or subtracted from each coordinate, versus multiplied which changes the size of the hat (as occurred in the prior problem). During the *What If...?* students distinguish rules that produce similar figures from rules that do not, recognizing the role that multiplication plays in scaled drawings or similarity relationships. The *Now What Do You Know?* not only provides an opportunity to discuss algebraic rules but also sets the stage for work on proportional relationships in the unit *Comparing and Scaling: Developing Proportional Reasoning in the Context of Number (Quantities)*.

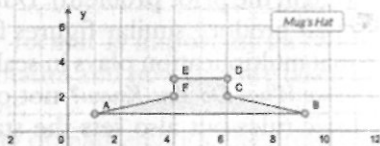
Connecting the Mathematics Problem and the Student Spaces

One lesson learned relates to the interconnectivity between the presentation of a mathematics problem and a student's individual and collaborative workspaces. In paper-and-pencil classrooms, curriculum materials and student notebooks are typically separate resources. In a digital environment, these resources can connect—students can access the problem and their workspaces simultaneously. In our development work, presentation of a mathematics problem progressed along a continuum from: (1) containing the problem and the notebook within the same section of the platform; to (2) separate sections for the problem and the notebook in the platform, with no interactive features between them; to (3) separate sections for the problem and the notebook, with interactive features between the sections. Figure 12.3 illustrates the placement of components of the digital platform at three development stages.

In the early development portion of Figure 12.3, tiles exist for students to access the various components. For example, student prompts and questions are embedded within some of the workspace tiles. This is not ideal for an inquiry-oriented classroom, as students need the authority and autonomy to generate their own work. Additionally, these separate tiles require students to navigate and manage multiple tiles on a screen, re-sizing and tracking as they move forward with the problem. From a task design perspective, there are limited features for presenting the problem, such as formatting text, providing labels for problem headers (*Initial Challenge*, *What If...?*, *Now What Do You Know?*). Due to a connection between the problem and the student notebook, students' notebook tiles are linked to each other so that students can access evidence of student thinking from each other.

Figure 12.2*Example of the CMP STEM Problem Format***Problem 2.2: Hats Off to the Wumps: Changing a Figure's Size and Location****Initial Challenge**

Zack experiments with multiplying Mug's coordinates by different whole numbers to make other characters. Marta asks her uncle how multiplying the coordinates by a decimal or adding numbers to or subtracting numbers from each coordinate will affect Mug's shape. He gives her a sketch for a new shape (a hat for Mug) and some rules to investigate.



	Mug's Hat	Hat 1	Hat 2	Hat 3	Hat 4	Hat 5
Point	(x, y)	$(x + 2, y + 3)$	$(x - 1, y + 4)$	$(x + 2, 3y)$	$(0.5x, 0.5y)$	$(2x, 3y)$

- Look at each rule and predict what will happen to the hat with each rule.
- Test each rule. How does your result compare with your prediction?

What If...?**Situation A. Writing New Hat Rules**

Several members of the computer club wrote different design criteria that would produce hats similar to the original Mug hat. What rule would you write for each design?

Syrah's Design

The side lengths are one third as long as Mug's hat.

Joe's Design

The side lengths are 1.5 times as long as Mug's hat.

Viola's Design

The hat is the same size as Mug's hat but has moved right 1 unit and up 5 units.

Kathy's Design

The image is in another quadrant of the graph.

Situation B. Raymond's Claim about Negative Numbers and Rules**Raymond's Claim**

If you multiply each coordinate by a negative number, the image is similar but smaller.

Is he correct? Explain.

Situation C. Isaiah's Challenge: Putting the Hat on Mug**Isaiah's Challenge**

I think it is possible to write a rule that will put Mug's hat on Mug. My group will work on finding the correct rule.

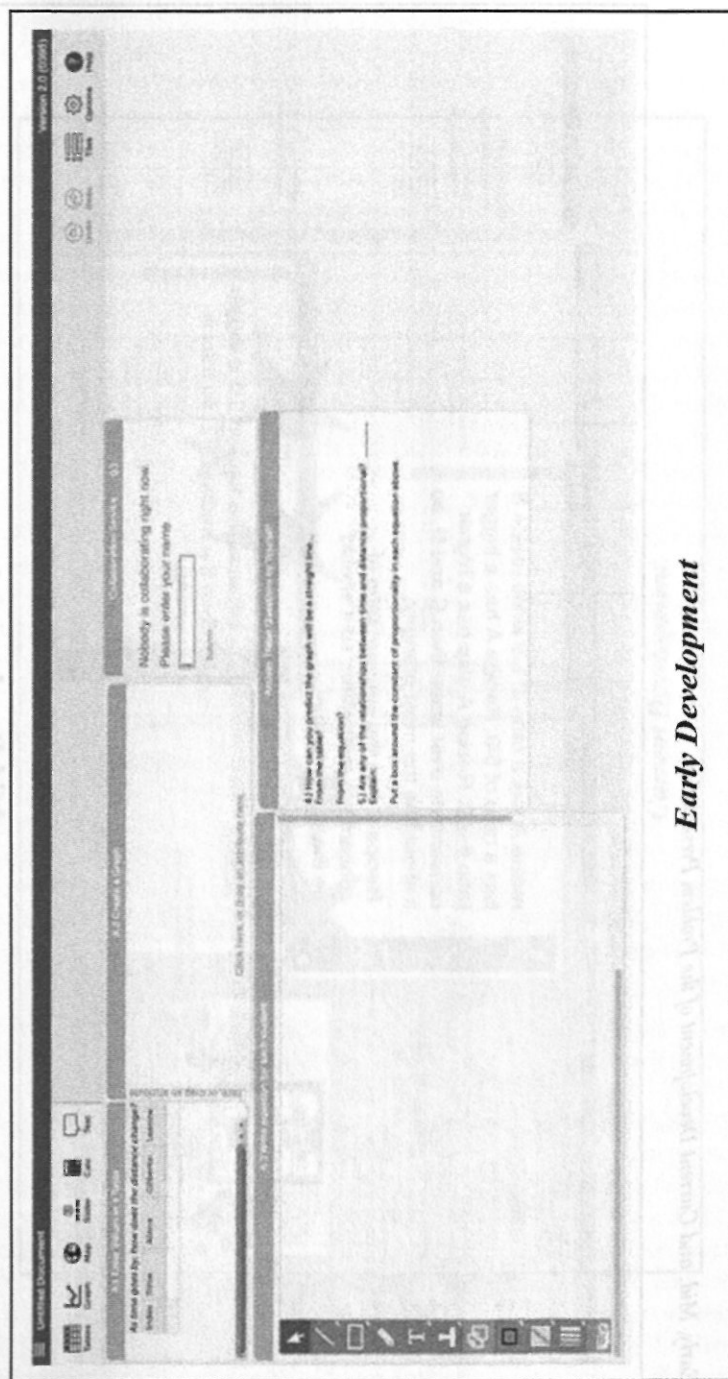
Is this possible? Why?

Now What Do You Know?

If the coordinate rule creates a similar figure, how can you use the rule to predict the side lengths of the image? The location of the image on the coordinate grid?

Figure 12.3

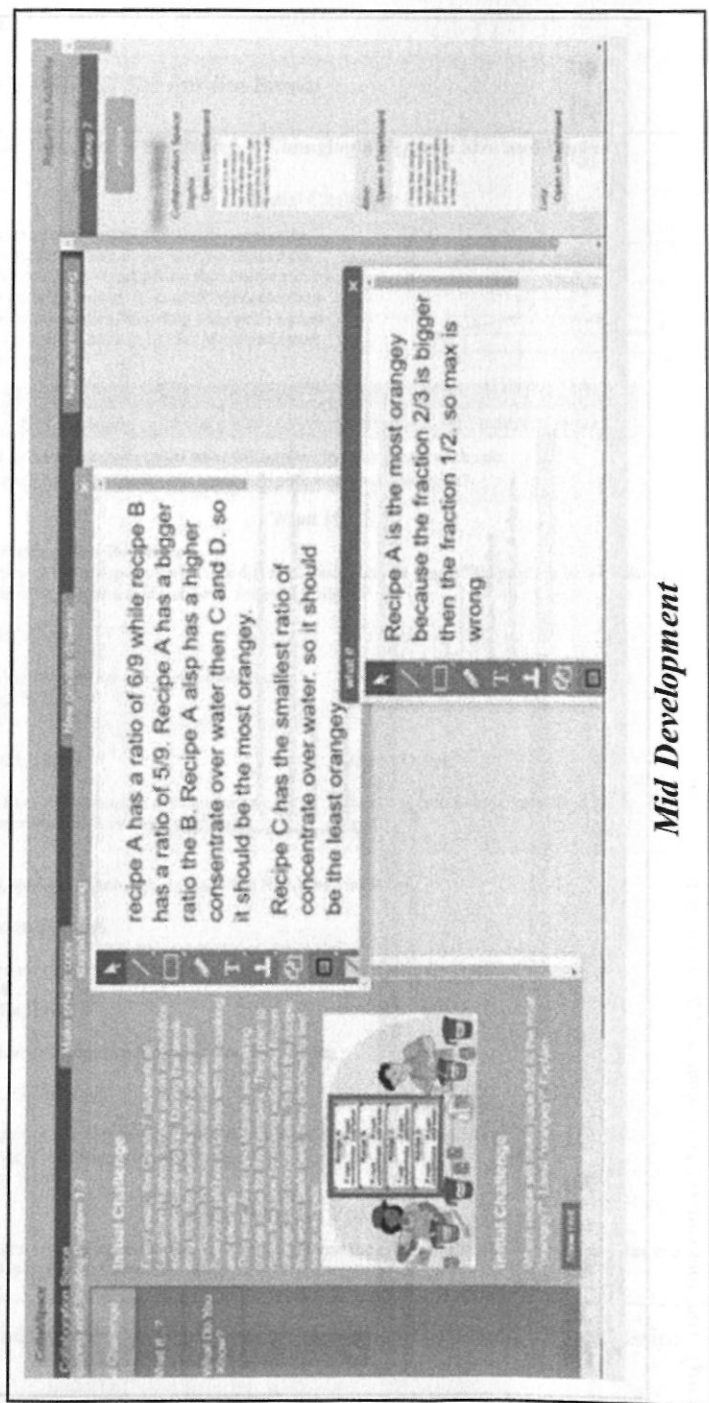
Early, Mid, and Current Development of the Problem Presentation



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Figure 12.3 (Continued)

Early, Mid, and Current Development of the Problem Presentation

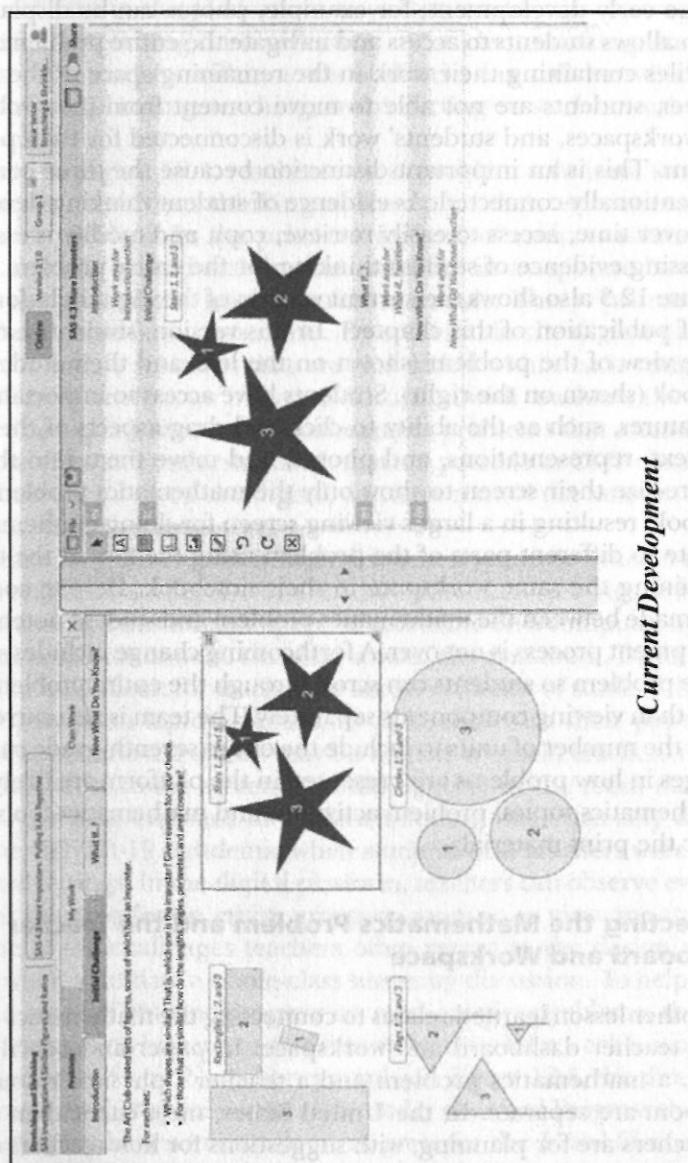


Mid Development

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Figure 12.3 (Continued)

Early, Mid, and Current Development of the Problem Presentation



Current Development

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The middle portion of Figure 12.3 shows the mid development of the digital platform. In contrast to the early development, a separate tile contains the mathematics problem in its entirety. The formatting is more advanced than the early development; for example, photos can be displayed. This version allows students to access and navigate the entire problem. Students move tiles containing their work in the remaining space of the platform. However, students are not able to move content from the problem into their workspaces, and students' work is disconnected for each part of the problem. This is an important distinction because the three components are intentionally connected. As evidence of student thinking develops and grows over time, access to easily retrieve, copy, and modify is essential, as is accessing evidence of student thinking for the entire problem.

Figure 12.3 also shows the current version of the digital platform (at the time of publication of this chapter). In this version, students have a side-by-side view of the problem (shown on the left) and their student digital notebook (shown on the right). Students have access to important interactive features, such as the ability to click-and-drag aspects of the problem (e.g., text, representations, and photos) and move them into their notebook; re-size their screen to show only the mathematics problem or their notebook, resulting in a larger viewing screen for doing mathematics; and navigate to different parts of the problem using the tabs at the top, while maintaining the same workspace in their notebook. Despite connections being made between the mathematics problem and student notebooks, our development process is not over. A forthcoming change includes streamlining the problem so students can scroll through the entire problem at once, rather than viewing components separately. The team is also currently scaling up the number of units to include the entire seventh-grade curriculum. Changes in how problems are presented in the platform are likely to occur as mathematics topics, problem activities, and mathematics tools are written for the print materials.

Connecting the Mathematics Problem and the Teacher Dashboard and Workspace

Another lesson learned relates to connecting the mathematics problems to the teacher dashboard and workspace. In paper-and-pencil environments, a mathematics problem and a teacher's physical resources in a classroom are separate. In the United States, most curriculum resources for teachers are for planning, with suggestions for how teachers can enact the mathematics problems. The curriculum materials provide teaching resources, aids, and lab sheets that can be printed and used during class activities. Since the beginning stages of developing a digital platform, the project team linked the teacher dashboard to the student digital col-

laborative platform because the CMP curriculum materials reflect the understanding that teaching and learning are inextricably linked together (Edson et al., 2019). The team progressively modified the design of mathematics problems in the platform in ways that would support teachers in their planning, teaching, and reflecting on student thinking, including features so that teachers within a school district can collaboratively work together around planning, teaching, and reflecting on student work (Edson & Phillips, 2021).

As shown in Figure 12.4, teachers access problem solutions, strategies, and examples of student thinking as they plan their enactment of the mathematics problem. In the print curriculum, oftentimes solutions are minimal, contain limited elaborations, and are in a separate booklet or found in the back of the teacher guide materials. This is primarily due to publishers' page limit constraints. By contrast, in the digital platform, teachers can toggle solutions that are embedded within each component of a problem. Written as an informal discussion with teachers, these solutions provide explicit answers to mathematics problems that attend to the various strategies and understandings that are possible in CMP classrooms. And because the solutions are digital, teachers control the amount of content shown on their screen.

The team also developed a digital teacher space so teachers could access—in real-time—students' work for the entire class (see Figure 12.5). It was important that this teacher space be accessible on a computer or tablet so teachers could continue to circulate around the classroom. During class, it is often more difficult for teachers to access evidence of student thinking that is displayed on laptop screens, as compared with their paper-and-pencil work, because the screen may be angled or small, teachers need to be physically close to the screen, and the lighting in the room may limit visibility. Accessing evidence of student thinking was especially difficult during the COVID-19 pandemic when students and teachers were not in face-to-face settings. In the digital platform, teachers can observe evidence of student thinking for an entire group or zoom in to view one student's work. One of the challenges teachers often report to the design team is deciding when to initiate a whole-class summary discussion. To help teachers have a sense of student progress on mathematics problems, the team provides analytics on how many students in the class have work initiated for each component of a problem. For example, in Figure 12.5, the three icons in the vertical teacher space on the right under the word *Progress* show that 21 of 26 students have some work-in-progress for the *Initial Challenge*, 11 of 26 students for the *What If...?*, and 5 of 26 students for the *Now What Do You Know?* Another challenge that teachers experience in classrooms is identifying evidence of student thinking to highlight in a class discussion. By clicking on the *Initial Challenge*, *What If...?*, and *Now What Do You Know?*

icons on the right under *Progress*, the work of every student is automatically scrolled so the teacher can view all evidence of student thinking for that problem component, rather than manually scrolling through each individual student's workspace. Because all work shown in the teacher dashboard is synchronous and updates in-the-moment, the work displayed is current work in progress by students. Teachers can also navigate to the published work and see the version of work posted to the entire class.

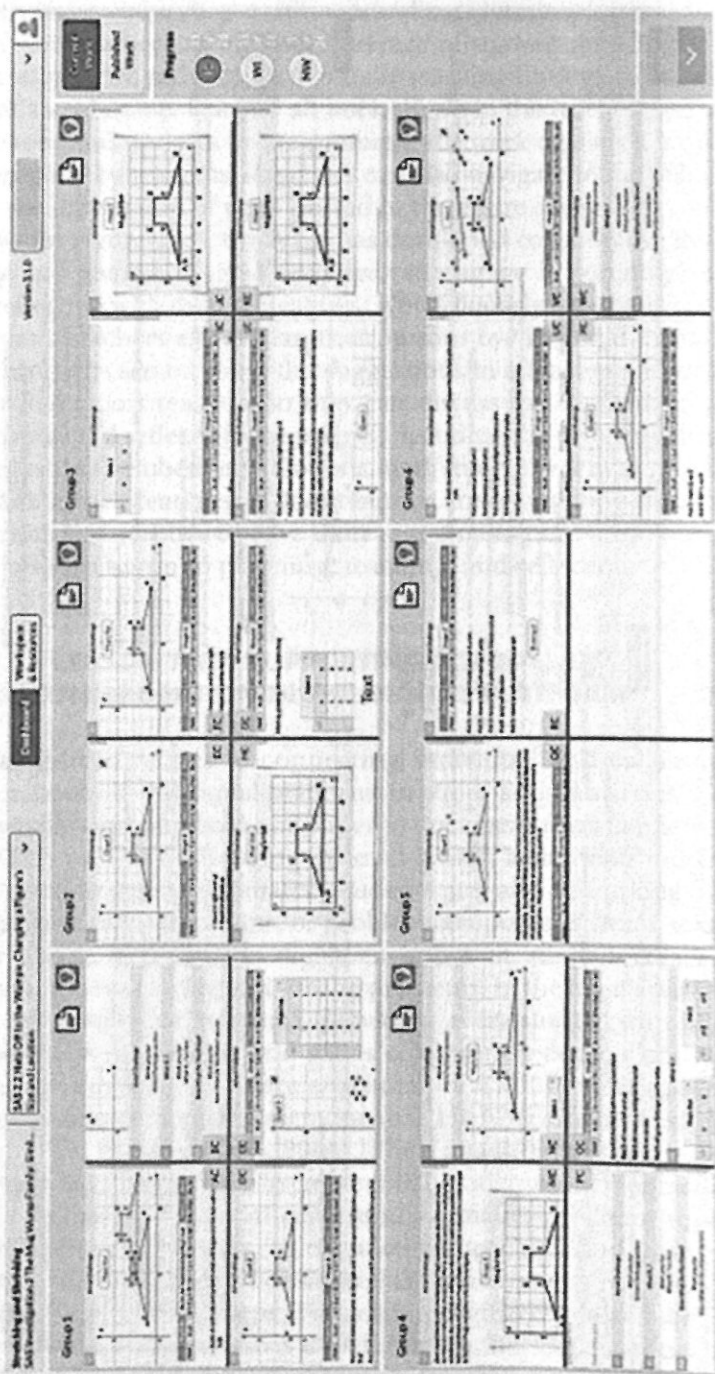
As shown in Figure 12.6, the team has developed collaborative features of sharing and commenting so teachers can engage in planning, teaching, and reflection with their colleagues, synchronously or asynchronously. Because many teachers either plan their lessons by viewing the problems that their students see or using the suggestions in a teacher's guide, it is important to support teachers so they can discuss the curriculum, planning, teaching, and reflection documents, including the problems, teacher guide suggestions, embedded solutions, and student work on problems. These collaborative features of commenting and circulating documents allow teachers and coaches to have daily and ongoing conversations, support, and resources around planning, teaching, and reflection.

LESSON TWO: SUPPORTING A MODEL OF COLLABORATION IN THE DIGITAL PLATFORM

The second lesson relates to connecting individual and collaborative student notebooks in the digital platform. In paper-and-pencil classrooms, students use physical notebooks or paper to document their mathematical thinking. This may be challenging in small groups as students' work may be upside down to their groupmates. Students may also be working on different strategies, representations, or problem components. Some teachers create worksheets. However, in a digital environment, students create their own notebooks for exploring and solving problems. In the team's past experiences in mathematics classrooms, providing every student with laptops often shuts down discussions and stifles cooperation and collaboration. In thinking about ways to enhance enactment of CMP, the team positions collaboration through how it is operationalized in CMP classrooms (Edson & Phillips, 2021; Lappan et al., 2004). The Launch-Explore-Summarize instructional model frames how to create collaborative and discourse-based workspaces so that students can explore mathematics problems together while using individual laptops. To enhance the teaching and learning of mathematics, the project team considered the participant structure of students in small- and whole-groups. The team recognized that collaboration often has different interpretations depending on the specific educational setting. For example, collaboration can involve multiple people working

Figure 12.5

Teacher Feature: Teacher Dashboard and Student Progress on Mathematics Problems



Source: Connected Mathematics Project (2023). (Reprinted with permission.)

Figure 12.6

Teacher Feature: Teacher Comments to Network Teachers and Coaches

The screenshot displays the SAS 2.2 software interface, which is a web-based platform for mathematics education. The interface is divided into several sections:

- Top Bar:** Includes the title "SAS 2.2 Help Off to the Winners" and a version number "Version 3.1.0".
- Left Sidebar:** Contains navigation links such as "Dashboard", "Workbooks", "Resources", "Problem", "Teacher Guide", "Student Workbooks", "My Work", "Class Work", "Comments", "Initial Challenge", "What's New", and "New What Do You Know?".
- Main Content Area:**
 - Problem Section:** Contains the text: "Zack experiments with multiplying Mug's coordinates by different whole numbers to make other characters. Now he asks her to multiply the coordinates by a decimal or adding numbers to get subtracting numbers from each coordinate will affect Mug's shape. He gives her a sketch for a new shape (a hat for Mug) and some rules to invent a game." Below this is a coordinate plane with a shape labeled "Mug's Hat" and vertices A, B, C, D, E, F, G. The vertices are located at approximately (1, 1), (6, 1), (6, 2), (4, 2), (4, 3), (1, 3), and (1, 1) respectively.
 - Initial Challenge Section:** Contains instructions: "Click on the arrow on the left side of your screen to get to 'My Resources'. Click on the Problem tab. The initial challenge should now be showing." Below this is a text box for "Read IC and write prediction of what will happen to the hat with each rule." and a "Drag over the rules. Click to add a text box and write your predictions by yourself without discussion with your group." Below this is a text box for "When everyone in your group is done with predictions, turn on the visibility by clicking the share on. Click the main screen to turn the 4 up viewers. Read through the predictions your other group members made." Below this is a table with columns "Point", "x", "y", "x + 2", "y + 4", "x - 1", "y + 4", "x + 2", "y", "x - 1", "y + 4", "x + 2", "y", "x - 1", "y + 4". The table is currently empty.
 - Initial Challenge Section (continued):** Contains instructions: "Continue working on the IC by dividing up the five hats amongst your group. Continue checking the 4 up view to see all the hats from your group members. When your group is finished with the IC, move on to the What If Situations." Below this is a text box for "Focus on Sit A. Then move onto Sit B if time." Below this is a text box for "Situation II: Will the image be similar or congruent? In what ways is the hat the same as or different from the original hat? Extension: What happens if you only multiply one of the coordinates by a negative number?" Below this is a coordinate plane with a shape labeled "Mug's Hat" and vertices A, B, C, D, E, F, G. The vertices are located at approximately (1, 1), (6, 1), (6, 2), (4, 2), (4, 3), (1, 3), and (1, 1) respectively.

Source: Connected Mathematics Project (2023). (Reprinted with permission.)

together toward a shared learning goal, or it can be more cooperative with people working separately on a portion of a group product that is later combined into a single product (Jeong & Hmelo-Silver, 2016). These different interpretations have substantial implications for how technology supports collaborative learning. Here are sample questions the project team considered as it took up the challenge of determining a digital platform that connects individual and collaborative student notebooks:

- Do students share control over one tool in a workspace, like a marker on poster paper?
- How do collaborative workspaces relate to individual workspaces? Should individual workspaces exist?
- Whose work belongs to whom in different collaborative interpretations? What if a representation from a collaborative model gets deleted?

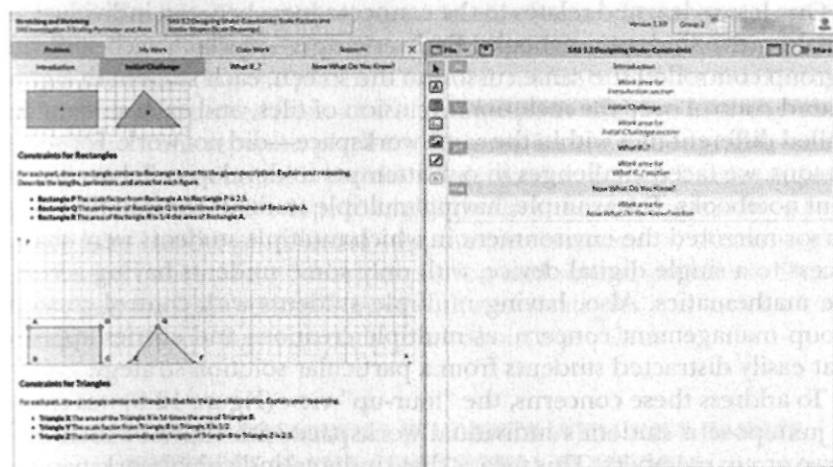
Platform Design Feature: Individual and Collaborative Student Notebooks

The digital notebooks contain several individual and collaborative features for students. Individually, students can access the CMP curriculum, and can click-and-drag text, graphs, and tables into their individual workspace (see Figure 12.7). Students can mark up or create new artifacts using tools such as text, tables, graphs, images, drawings, and more. Students can upload photos of their paper-and-pencil work. Students can embed work that is shared or published by others into their workspace and modify it. Students can create entries that span across problems and investigations, such as different strategies, key terms, *Summarize* notes, discussions, and mathematical reflections. Work is automatically saved on the platform.

Collaboratively, when students log onto the platform, they assign themselves to groups of four or are assigned by the teacher. Students access a “four-up” view (see Figure 12.8) where they access—in real time—the work of their groupmates, easily incorporating the work of others into their own. Figure 12.8 shows evidence of student thinking for the mathematics problem shown in Figure 12.7. As shown in Figure 12.8, the upper left-hand workspace (quadrant) is the students’ individual workspace, and the three workspaces shown in the other quadrants are the individual workspaces from their group teammates. Students can discuss strategies and assign parts of the problem to individuals and then combine their strategies into a complete solution that can be shared with the class. Students in their small groups publish work to other groups and use it during whole-group discussions.

Figure 12.7

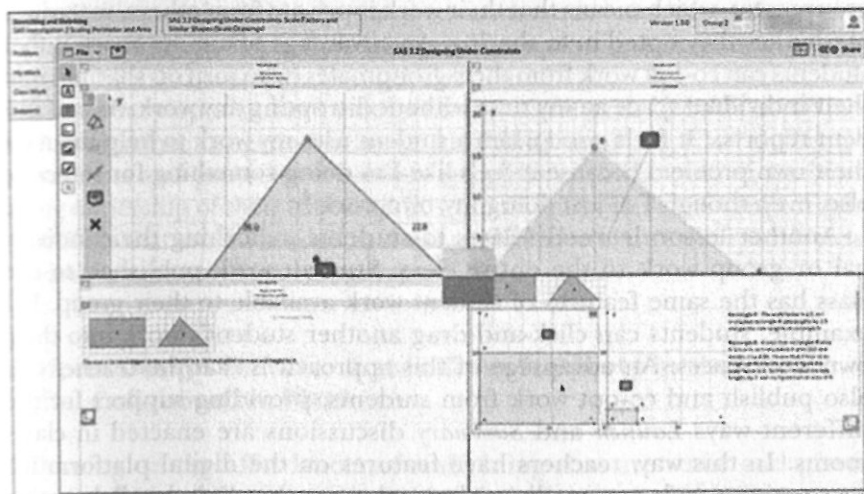
Curriculum-Embedded Individual Student Workspace



Source: Connected Mathematics Project (2023). (Reprinted with permission.)

Figure 12.8

Collaborative “Four-Up” View of Work



Source: Connected Mathematics Project (2023). (Reprinted with permission.)

Connecting Individual and Collaborative Student Notebooks

One lesson learned relates to the connectedness between individual and collaborative student notebooks. Early attempts—in which each student in a group controlled the same cursor on the screen, each student in a group shared control over the inclusion/exclusion of tiles, and each student controlled different tiles within the same workspace—did not work. For several reasons, we faced challenges in our attempts to develop collaborative student notebooks. For example, having multiple students controlling a single cursor mirrored the environment in which multiple students were sharing access to a single digital device, with only some students having access to the mathematics. Also, having multiple students with control created a group management concern, as multiple creations and entries appeared that easily distracted students from a particular solution strategy.

To address these concerns, the “four-up” view (Figure 12.8) was created to juxtapose a student’s individual workspace with those of their other three group members. This means that students’ individual workspaces are the same as their collaborative workspaces when they decide to collaborate; if they choose not to share their work, then other students cannot access their individual workspace. Typically, students ask questions within their group or provide time for others to work individually prior to collaborating. If all students in the group decide to share their work, they generally discuss their plan for moving forward before starting to share. Students also have the option for an individual workspace that is not connected to their groupmates, which means that their work is private from others, regardless of whether they opted in to sharing. An advantage of our approach is that students can co-opt work from their groupmates (who turn on sharing) into their individual space at any time without disrupting any work. As one student reports, “It feels good when a student uses my work to help them on their own problem because it feels like I’m doing something for someone else, even though I’m just doing my own work.”

Another lesson learned relates to students publishing their individual or group work to the entire class. Student work published to the class has the same features of student work available to their group. For example, students can click-and-drag another student’s work into their own workspaces. An advantage of this approach is that the teacher can also publish and co-opt work from students, providing support for the different ways *Launch* and *Summary* discussions are enacted in classrooms. In this way, teachers have features on the digital platform for structuring whole-group discussions, that is, the digital collaborative platform positions and leverages student work that can easily be used in whole-group discussions.

A forthcoming feature of the digital platform will allow students (and the teacher) to play back any work so that it can be viewed like a short video. This feature relies on sequences of the undo and redo features to provide a timeline of work. The unique aspect of this feature is that the timeline spans the entire workspace, not just individual tiles located within it. For example, by activating the playback feature, students and the teacher can see when the user moved from a table to a graph to their written response, which differs from separate playback features for each tile (graph, table, drawing, etc.). In essence, this provides a mechanism for students to unpack “finished” work done over time to highlight their underlying thinking processes. It also has the potential to support conversations on the strategies that are used or abandoned when exploring and solving problems. This is critical when students are confronted with new strategies and look for connections to the ways they currently think about a problem.

LESSON THREE: PROVIDING STUDENTS WITH JUST-IN-TIME SUPPORTS IN THE CMP DIGITAL PLATFORM

The third lesson focuses on connecting students with curriculum-provided and teacher-generated *just-in-time* supports (Novak et al., 1999), with the goal of moving a student’s learning of mathematics forward in a classroom. In many curriculum materials, it is common for scaffolding to take the form of adaptive tutoring, with the goal of improving a student’s speed, accuracy, and automaticity in performing routine mathematical procedures (Bakker et al., 2015). In these environments, learning mathematics becomes reduced to focusing on the performance of mathematical operations rapidly and correctly. In a problem-based curriculum, however, the goal is to develop a student’s deep understanding and problem-solving ability. A balance is needed between providing an appropriate challenge for students and providing necessary supports, with the goal of students taking ownership of their learning (Edson, 2014, 2016). The CMP prompts to students that are embedded in the digital platform are called *just-in-time supports*.

Platform Design Feature: Just-in-Time Supports in the Digital Collaborative Platform

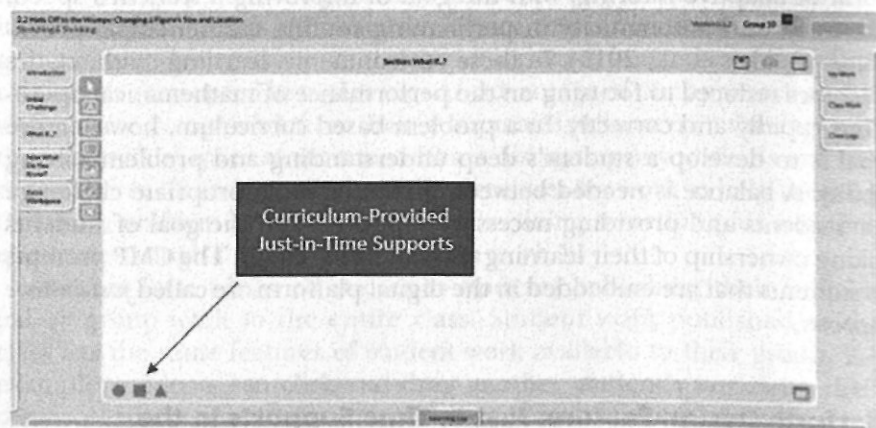
Drawing on the affordances of scaffolding that are static and given beforehand (e.g., Miyazaki et al., 2015; Schukajlow et al., 2015; Tropper et al., 2015) and scaffolding that is dynamic and used on-the-fly (e.g., Abdu et al., 2015), the team has developed two options for how specific supports are

revealed as needed to students. One option is *curriculum-provided just-in-time supports*, which students select individually as they explore the problems. The other option is *teacher-generated just-in-time supports*, where teachers generate and send students prompts found in the student digital collaborative platform.

The curriculum-provided just-in-time supports are options that students can select on the digital platform. As shown in Figure 12.9, students can click on different shapes located at the bottom of their workspace. In Problem 2.2 (Hats Off to the Wumps, shown in Figure 12.2), examples of curriculum-provided supports include: (1) *Initial Challenge*—To predict what will happen to the hat with rules, recall the relationship between the rules to draw Zug, Lug, Bug, and Glug and its similarity in Problem 2.1¹; (2) *Initial Challenge*—In Problem 2.1, how is a rule for adding or subtracting a number to the x - or y -coordinate different from a rule with multiplying a number?; and (3) *What If...?*—In *Initial Challenge* (of Problem 2.2), which rule is related to multiplying a number to the coordinates? What did the rule change in the hat? These prompts are only possible with the CMP STEM Problem format and the underlying learning progressions of the curriculum materials (Edson et al., 2019).

Figure 12.9

Curriculum-Provided Just-in-Time Supports



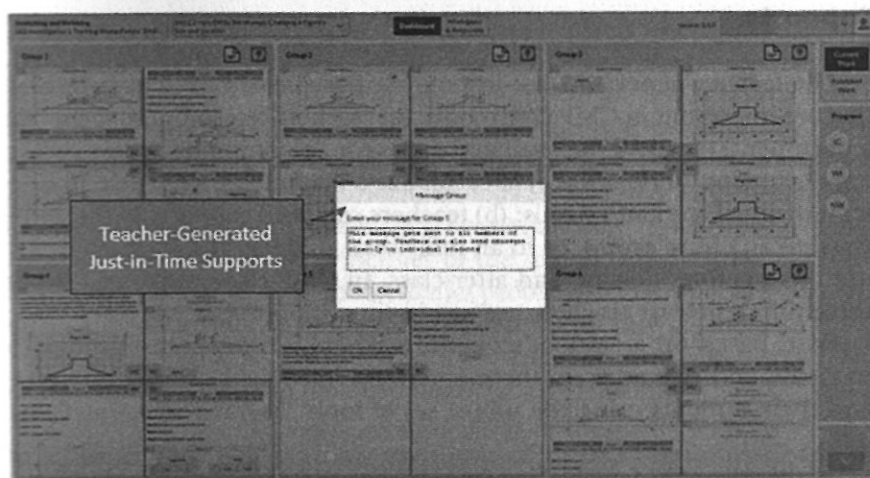
Source: Connected Mathematics Project (2023). (Reprinted with permission.)

As elaborated in Edson and Phillips (2021), the teacher-generated just-in-time supports are mechanisms where teachers can create prompts, questions, or comments, and send them to individuals, groups, or entire classes of students. For example, Figure 12.10 shows an example from the

digital platform, showing how a teacher might create a message that can be sent to a group of students. The icons in the digital platform are in the dashboard so that teachers can monitor evidence of student thinking. The icons can also be found in the teacher workspace area, where they can access documents produced and published by students.

Figure 12.10

Teacher-Generated Just-in-Time Supports



Source: Connected Mathematics Project (2023). (Reprinted with permission.)

Lessons Learned on the Curriculum-Provided Just-in-Time Supports

The curriculum-provided supports are no longer available on the digital collaborative platform. The prompts were offered as additional student learning opportunities when the mathematics problems were redesigned. The curriculum-provided supports were removed for three reasons. First, the redesign of the mathematics problems helped support students in their mathematics thinking. Second, curriculum developers cannot predict the specific supports needed to move students forward in solving a problem. Third, in a digital environment, students have access to a variety of other resources that can be leveraged as on-demand supports, including real-time access to the work of their groupmates, real-time access to published student work from other groups, mathematical representations moved from the curriculum into their notebooks

to serve as a starting point for their thinking, and teacher-generated supports that can be released to students. As more features to support students are designed and developed for digital platforms, it is inevitable that earlier features may become superfluous over time. This lesson learned is consistent with a similar kind of support mechanism related to learner-controlled scaffolding at the high-school level that was not needed (Edson, 2014, 2016).

Lessons Learned on the Teacher-Generated Just-in-Time Supports

The teacher-generated just-in-time supports have three characteristics that are important in CMP classrooms: (a) teachers can compose them (like a document) using all the available tools (e.g., planning document, teaching document, student work) to customize a mathematics problem to meet an individual student's needs; (b) teachers can send supports to the entire class, to an entire group, or to an individual student; and (c) teachers can use them before, during, and after class. In CMP classrooms, we learned three different ways teachers use just-in-time supports.

First, based on a student's needs, teachers use just-in-time supports to create and customize in-the-moment interactions between themselves and their students using the robust set of tools. As one teacher explains:

In the classroom, I am looking for kids who aren't doing anything, but I'm also looking for work that I want to highlight and talk to the whole group about. I'm not going to stop and have a "you should be doing" conversation with every other kid. I don't like doing that. But so it would be a great opportunity to be able to just shoot them a sticky note that says, "you know, hey, I noticed you didn't do much here. Do you have questions? Do you want to meet with me at lunch?"

Although teachers report that using the just-in-time supports during class is challenging if they do not have a tablet in the classroom, some have found this feature useful.

Second, teachers predominately create and send just-in-time supports when they monitor evidence of student thinking after class. In paper-and-pencil environments, it is not feasible for teachers to look at evidence of student thinking after class because students' notebooks leave the classroom with the students. In a digital environment, however, teachers can log into a digital platform to access student work, post comments on their solution strategies, and offer questions for students to reflect on their thinking.

Third, teachers can customize a mathematics problem delivered digitally to meet students' needs. Examples include questions for students to consider during the prompt, or additional/modified prompts and questions for students to assess their learning while they explore and solve problems. In practice, teachers prepare these activities before class and use them during lesson launches or formatively to assess student thinking at the end of class.

CONCLUSION

In this chapter, I have reported on lessons learned when developing a digital collaborative platform for students and teachers who use the Connected Mathematics Project curriculum (Phillips et al., 2025). The research team is unaware of other mathematics curricula that purposefully leverage digital technologies for high-level collaboration. The philosophy and design of the CMP materials prioritizes collaboration, which necessitated a careful examination of all possible resources that could be incorporated into the platform. The design principles of the digital collaborative platform focused on (1) reimagining mathematics problems, (2) supporting a model of collaboration, and (3) providing students with just-in-time supports. These design decisions led to changes in enacted experiences within CMP classrooms, resulting in enhanced teaching and learning of mathematics. Individual, collaborative, and classroom documents and artifacts created by students and their teachers are elevated in this digital platform. In this way, the resulting digital collaborative environment provides students and teachers with a more egalitarian environment than paper-and-pencil classrooms where conventional print materials drive enactment decisions.

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ENDNOTE

1. In Problem 2.1, students explore what rules will make similar shapes by considering coordinate rules. They draw a character Mug Wump and use the given rules to find other Wump characters: Zug ($2x$, $2y$), Lug ($3x$, y), Bug ($3x$, $3y$), and Glug (x , $3y$). Students compare rules and figure attributes and determine which family members are similar to Mug and which figures appear not to be similar and thus “imposters.”