3

MOVING FROM INDIVIDUALIZED INSTRUCTION TO TECHNOLOGY FOR COLLABORATIVE LEARNING

● Instead of using screens to enable disconnected, individualized
● learning, what if we leveraged technology to facilitate
● mathematical discourse and collaboration?

THIS CHAPTER INCLUDES two cases that illustrate teaching fraction equivalence with technology tools in an Algebra I class. As you read each of the following cases, consider how and what math is being taught, how technology is being used, and how the two connect. After reading and reflecting on the two cases, compare your insights and connections with what research has to say about two big ideas illustrated in the cases: *Technology as a Collaborative Tool* and *Teaching Practices that Support Mathematical Learning.* You might also take a moment to examine how each of the lessons aligns with standards for math content, mathematical practices; and ISTE Standards for students, educators, and coaches. Standards alignment is offered at the end of the chapter for your reference.

Technology as a Collaborative Tool

Technology can be used to connect, collaborate, and communicate among students and teachers. Indeed, collaboration and communication are consistently listed among digital age skills that educators wish to develop among students. Simultaneously, teachers and administrators face calls for more personalized learning, ranging from the ISTE Standard for Educators, 5a. *Use technology to create, adapt, and personalize learning experiences that foster independent learning and accommodate learner differences and needs,* to individualized learning programs marketed by tech companies. For teachers looking to address all of these goals, there may be perceived tension between using technology to collaborate and communicate and using technology to personalize learning. In a math classroom, how can students communicate and collaborate if each student is working individually at their own pace? How can a teacher encourage mathematical discourse if each student is at a different place in a unit facilitated by a personalized learning program? Reconciling these tensions is an essential component of utilizing technology in a way that supports students' individual needs.

Teaching Practices that Support Math Learning

Well-known learning theorist Lev Vygotsky wrote: "What a child can do in cooperation today, [s/]he can do alone tomorrow." Teaching that encourages students to engage in mathematical discussions not only supports cooperation and collaboration, but also provides them with opportunities to articulate and refine their reasoning through language and multimodal forms of communication. Classrooms rich in mathematical discourse support students' mathematical learning by allowing them to collaboratively develop shared understanding. By honoring and discussing students' diverse contributions and ways of thinking, teachers can support learner differences and needs. Mathematical discourse communities can differentiate for students' individual needs by meeting students where they are in their learning, and leveraging partner, small-group, and whole-group interactions to build upon the math that students know and can do. A focus on collaboration and communication in the classroom can also emphasize reasoning and concepts, rather than narrowly defining math in terms of right or wrong answers. Rather than isolating students to learn math at individual screens, technology can support classroom discourse communities that engage students in collaboration and mathematical communication.

In the following case, Ms. King's Algebra I class is learning about comparing linear functions using tables, graphs, equations, and verbal descriptions. Consider how she integrates technology into the lesson and her math teaching practices. How does she use technology to encourage communication and collaboration? To what extent does technology and instruction support personalized learning experiences that accommodate learner differences?

⊙ CASE 3.1

Ms. King's Algebra I Comparing Linear Functions Lesson

OBJECTIVES
- Compare linear functions represented graphically, in tables, as equations, or by verbal descriptions.

Ms. King's classroom has 1:1 computers. Her school has recently begun encouraging more personalized learning experiences using classroom technology and free online open educational resources. The goal of this initiative is to improve students' performance on state assessments through more individualized learning experiences using technology. This aligns with Ms. King's goals of designing instruction that meets her students' diverse needs and strengths.

To implement personalized learning in her classroom, Ms. King and her students use Khan Academy. Through their free, online resources, she is able to set up her class; assign lessons, videos, exercises, and quizzes; and view students' progress and scores. She appreciates that the online resources save time that she would spend on grading, but realizes that she spends a similar amount of time setting up and monitoring the online class and data.

Since implementing personalized learning in her classroom, one of the challenges Ms. King has faced is pacing. There is tension between meeting the district's scope-and-sequence with their adopted curriculum while also allowing students to learn at their own pace in the online environment. She addresses this by starting each unit with lessons from the textbook, then giving students several days to work at their own pace to complete online lessons that are comparable to what is in her curriculum materials. A few days before the end of each unit, Ms. King will review and reteach using lessons from the textbook, and then her students will take the district's unit assessments.

Lately, Ms. King's class has been learning about linear functions and comparing across representations. Together as a whole group, Ms. King shows students the first Khan Academy video

in the Interpreting Linear Functions and Equations lesson, and answers student questions. After watching the video together, students may rewatch the video, proceed to new videos in the lesson, complete the exercises, or proceed to the next lesson about comparing linear functions. Students work online at their own pace until they have taken the online quiz for these two lessons. The videos, practice exercises, and quiz include finding equivalent fractions using numerals, bar models, area models of various shapes, and number lines. Exercises are numerical or selected-response.

Some students finish both lessons and the quiz in one day. For these students, Ms. King assigns enrichment work from the textbook or lets them work on homework. Other students are still struggling to earn a passing quiz score at the end of the second day. As students work online during class, Ms. King spends some of her time assisting those students. Other times, she monitors students as they work individually, making sure they are on-task. When she is not working with individual students or monitoring the classroom, she often checks student progress through the data available to her online.

Ms. King is happy to be contributing to the vision of more personalized learning in her school, but has some mixed feelings about how it is going. She hasn't noticed a major difference in unit test scores as compared to her colleagues who aren't using personalized learning in their classrooms, but she has data to show that her students are progressing through the lessons. She has noticed that the classroom is generally quieter during math now, but there is less opportunity for the partner and group work in math that she believes is important for learning math. Some students have had a more difficult time staying on task lately. Ms. King is excited about how she and her students are using technology for learning math, but continues to reflect on the right balance between personalized learning, her school's math curriculum, and her teaching philosophy in order to best meet her students' diverse needs.

Reflection Questions

Consider Ms. King's use of technology in this lesson. Based on her perception of students' needs and district preferences, she selected a technology that aligned with the math content she needed to teach.

- Would you consider this a technology-rich lesson? Why or why not?

- What was the purpose of Ms. King's technology use in this lesson?

- How did Ms. King's integration of technology advance the teaching and learning in this math lesson?

- What were she and/or the students able to do with technology that was different from or better than what could have been done without technology?

- Might the use of technology in this lesson hinder students' math learning in any way? Why or why not?

Next, consider the math teaching practices in Ms. King's lesson.

- What were Ms. King's goals for this math lesson?

- How did she address students' individual needs in this lesson?

- Would you describe this lesson as more teacher-centered or more student-centered? Why?

- To what extent did students have equitable access to learn and demonstrate their understanding in this lesson?

- Overall, what strengths do you see in this lesson? What opportunities do you notice?

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Mr. Lennon's Algebra I class is also learning about comparing linear functions. As you read about Mr. Lennon's lesson, consider how he integrates technology into the lesson and his mathematical teaching practices. How does he use technology to encourage communication and collaboration? To what extent does technology and instruction support personalized learning experiences that accommodate learner differences?

✖ CASE 3.2

Mr. Lennon's Algebra I Comparing Linear Functions Lesson

OBJECTIVES
- Compare linear functions represented graphically, in tables, as equations, or by verbal descriptions.

Mr. Lennon knows that some students continue to struggle with recognizing linear functions across multiple representations. He is using today as an extra lesson to supplement the lessons in his district-adopted curriculum materials. Before engaging students in comparing properties of functions, he has designed an online card sort, using Desmos, that gives them an opportunity to think and reason about functions presented in graphs, tables, equations, and contextual situations. He wants students to work together and discuss their reasoning, so he has assigned partners for whom he knows can work productively.

At the beginning of the lesson, Mr. Lennon pairs students, and asks one student from each pair to get a laptop from a cart in the back of the room. While students are getting their computers, he projects the student.desmos.com web address and class codes so that all students can log on promptly. He tells students that their task is to sort the linear function cards into four categories, and that they will need to discuss with their partners to decide on the categories. The card sort activity (shown in Figure 3.1) includes a total of 16 cards that could be sorted in a variety of ways depending on how students reason about them.

Figure 3.1 Linear function card sort.

As students work on the online card sort, Mr. Lennon views their results on the teacher.desmos.com dashboard. He accurately anticipates that some students will sort the cards by representation type, some will try to match a different type of representation for each of the four functions but make errors in matching some of the representations, and some students will successfully match the representation types for each of the four functions described. He invites three student pairs to explain their sort and categories to the whole group.

The first pair, Colin and Sonny, sorted by representation type. He displays their work on the board (see Figure 3.2) and asks them to explain their reasoning.

Sonny explains, "We saw four different kinds of problems, so we made a category for the functions that looked like this [points at symbolic equations], the tables of points, the graphs, and the word problems."

Mr. Lennon asks if the class agrees that those four categories make sense and that their grouping in those categories is accurate. No one indicates disagreement. "Let's look at another idea that Amaris and Maggie had for the categories." He displays their work, shown in Figure 3.3.
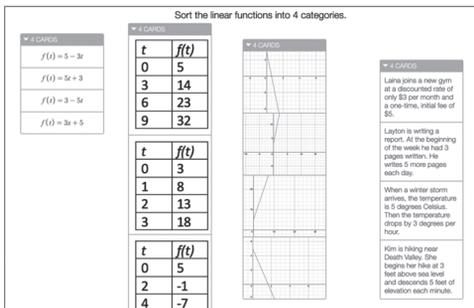
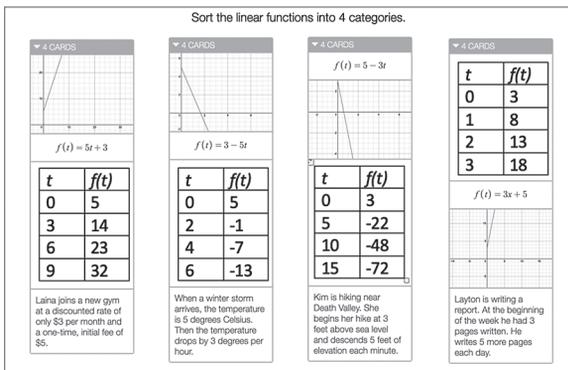**Figure 3.2** Colin and Sonny's card sort.

Figure 3.3 Amaris and Maggie's card sort.

"We sort of thought we were supposed to group them so that each category had one of each kind of function in it, and so they matched," says Maggie.

Mr. Lennon reiterates, "Maggie and Amaris decided that each of their categories would have the same function, but represented in four different ways: graph, equation, table, and a contextual situation." He chose Amaris and Maggie to present, knowing their matches weren't accurate. Mr. Lennon suspects they are confusing slope and y-intercept, and that other students may be making the same errors, so he invites them to further explain their choices within each category.

Amaris tells the class, "The first one we could see was going up on the graph, so we knew that the numbers needed to be positive in the equation, and we could see that the numbers were going up in the table. It took us a while to figure out which word problem would fit, but because the fee was $5, we decided that one made the most sense."

"How did you decide that f(t)=5t+3 matched instead of f(t)=3t+5. You said that the numbers needed to be positive in the equation, but everything is positive in both of those equations. Can you tell us more about that?" asks Mr. Lennon.

"Because it starts at five, we picked the equation that starts with five," Amaris replies. A few students raise their hand. Mr. Lennon asks Meg to add to what Amaris said.

"I think even though the equation starts with five, because it's 5t, that means it goes up by five each time. Wouldn't that equation start at three? Because if we think of it like y=mx+b equations, then in f(t)=5t+3, five would be the slope, and three would be the intercept, which is like the starting point," adds Meg.

Mr. Lennon senses that Amaris and Maggie are unsure, so he gives the class a couple minutes of think-time to discuss in pairs and small groups. He suggests that they try some of the ordered pairs from the table to help them figure out which equation is accurate.

Amaris and Maggie come to agree with Meg's accurate assertion. "We see what Meg means now. It makes more sense if we switch the equations [f(t)=5t+3 and f(t)=3t+5]. We tried using the numbers from the table, like you said, and the first one with Laina and the gym works if the equation is f(t)=3x+5, but you don't get the right numbers with f(t)=3t+5."

"Malia and Jordin have four categories that look a lot like what Amaris and Maggie have come up with. Let's take a look at theirs and see what we think about it." Mr. Lennon displays their work for the class to see (as shown in Figure 3.4). Students agree that their groupings make sense. He asks them to explain one of the categories with negative slope.
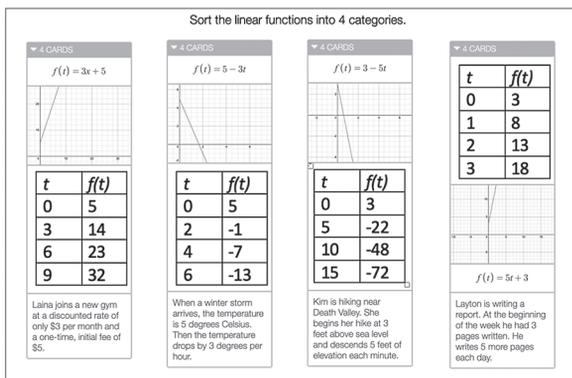

Figure 3.4 Malia and Jordin's card sort.

Jordin explains, "With the Death Valley one, we could see that the graph crossed the axis at three, and the line was going down pretty steep so we picked f(t)=3-5t as the equation. That one also matches with the table that shows zero and three, and then goes down. When we looked at the word problem part, it says she started at three feet above sea level so that would be positive three, and then it goes down five feet per minute. At first we thought maybe the table was wrong because it goes down by more than five, but then we realized that it was showing five minutes, not one minute, so it was ok."

After the whole-group discussion about different representations for linear functions, Mr. Lennon tells the class that they are going to use what they just discussed, and compare some of the properties of linear functions that are shown using different representations. He tells them to go to Khan Academy and find the Comparing Linear Functions lesson. Students are expected to continue working as partners to successfully complete the two sets of practice exercises and quiz. Mr. Lennon can monitor their progress though the Khan Academy teacher dashboard and provide one-on-one support, as needed. Some students successfully proceed straight to the practice exercises and quiz. Others view some of the videos to help them with the exercises. As Mr. Lennon circulates around the classroom to monitor and provide support, he reminds students of the videos and hints accompanying practice problems. He notices some are struggling to do the work in their head, so he encourages them to use the built-in calculator, or pencil and paper, to help them figure out the problems. Students who finish early can proceed to the next Khan lessons on Linear Models Word Problems.

When students are finished with the Khan Academy quiz, Mr. Lennon asks the class to go back to the Desmos tab from the beginning of class. He displays a question slide (the question is shown in Figure 3.5) that relates to the types of problems students just solved online. Still working with their partners on the laptops, students are asked to enter multiple-choice responses to the question about comparing three linear functions, each with a different type of representation. Mr. Lennon can see that most students answered the question correctly. He calls on one student to briefly explain his reasoning to the rest of the class.

Jesse explains, "For the first one, I plugged in three for t and got P=$33.50. For the second one, I just multiplied $5 times three days and added $10, so Kai has $25. For Trina, I figured that because three is halfway between two and four, then it would be $32, which is halfway between $28 and $36. Alex would have the most then."

Mr. Lennon goes to the next screen (the contents of which are shown in Figure 3.6), and asks students to select whether Alex, Kai, or Trina would be the first to earn $100. He encourages them to use scratch paper, and confer with their partner as they work on the problem.

Alex, Kai, and Trina are saving money to go to an amusement park. Who will have the most money saved on Day 3?

- o Alex is earning money by walking her uncle's dog. This function represents the amount of money, P, she earns per day, t:
  $P = 3.5t + 23$
- o Kai has $10 when he starts saving. He earns $5 per day helping his neighbor with her garden.
- o Trina earns money for doing chores each day. The table shows her savings, P, on a given day, t.

T	P
0	20
2	28
4	36
6	44

Figure 3.5 Who will have the most money on day three?

Alex, Kai, and Trina are saving money to go to an amusement park. Who will be the first to earn the $100 needed for admission, food, and spending money?

- o Alex is earning money by walking her uncle's dog. This function represents the amount of money, P, she earns per day, t:
  $P = 3.5t + 23$
- o Kai has $10 when he starts saving. He earns $5 per day helping his neighbor with her garden.
- o Trina earns money for doing chores each day. The table shows her savings, P, on a given day, t.

T	P
0	20
2	28
4	36
6	44

Figure 3.6 Who will earn $100 first?

Fewer students correctly respond to this problem. With class time running out, Mr. Lennon asks students to jot the problem down in their notebooks, work on it more as homework, and be ready to discuss the problem at the beginning of class tomorrow.

Reflection Questions

Consider Mr. Lennon's use of technology in this lesson. As you reflect and discuss with colleagues, consider what happened in Mr. Lennon's lesson and how it compares with Ms. King's class.

- Would you consider this a technology-rich lesson? Why or why not?

- What was the purpose of Mr. Lennon's technology use in this lesson?

- How did Mr. Lennon's integration of technology advance the teaching and learning in this math lesson?

- What were he and/or the students able to do with technology that was different from or better than what could have been done without technology?

- Might the use of technology in this lesson hinder students' math learning in any way? Why or why not?

Next, consider Mr. Lennon's math teaching practices in this lesson and how they compare with the practices in the first scenario.

- What were Mr. Lennon's goals for this math lesson?

- How did he address students' individual needs in this lesson?

- Would you describe this lesson as more teacher-centered or more student-centered? Why?

- To what extent did students have equitable access to learn and demonstrate their understanding in this lesson?

- Overall, what strengths do you see in this lesson? What opportunities do you notice?

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What Does the Research Say?

The following research supports the use of technology as a collaborative tool:

- Technology allows for networking, communicating, and collaborating in increasingly sophisticated ways. In a digitally connected world, students from across the classroom, or across the world, can communicate and work collaboratively in real time. Decades of research has shown that student engagement in collaborative, connected learning environments can positively impact their motivation, conceptual understanding, and perseverance for solving challenging problems, and has been shown to be particularly impactful for struggling learners. Furthermore, studies involving collaborative interactions with technology have shown more equitable participation than what often occurs in classroom discussions absent of technology. (See, for instance, Beatty & Geiger, 2009; Goos, Galbraith, Renshaw, & Geiger, 2000; Hoadley, Hsi, & Berman, 1995; Hsi & Hoadley, 1997; Hurme & Jarvela, 2005; Riel, 1991; Roschelle et al., 2010; Scardamalia & Bereiter, 1993; Suthers, Toth, & Weiner, 1997; White, 2006)

- Use of technology as a collaborative tool aligns with prevailing learning theories in math education. Whereas technology-enabled personalized learning approaches overwhelmingly employ behaviorist approaches to teaching and learning math (Dishon, 2017), math education research has, for decades, emphasized and drawn upon constructivist and socio-cultural theories (Cobb, 1994) for supporting more equitable student learning through collaborative, inquiry-driven, and discourse-rich teaching approaches. Using technology as a collaborative tool aligns with theory and research in math education. Using technology to personalize learning with behaviorist approaches that do not afford collaboration and communication can disregard decades of research on teaching and learning math.

- When students spend a significant amount of class time engaged individually with technology, mathematical discussion in the classroom can decrease (Thomas, 2013). However, the opposite can be true when students engage in models of personalized learning that include opportunities to work collaboratively with peers. Technology can impact the nature of human interactions and the interactions among learners, teachers, mathematical knowledge, and learning contexts (Borba et al., 2016). Plainly stated, using technology as a collaborative tool while also promoting personalized learning goals is a complex endeavor for teachers of math.

Following are mathematical teaching practices that support student learning:

- In developing a framework of high-leverage, effective mathematics teaching practices, the National Council of Teachers of Mathematics (2014) highlights research-based principles of learning including, "Learners should have experiences that enable them to construct knowledge socially, through discourse, activity, and interaction related to meaningful problems" (p. 9). A body of research, conducted over decades, continues to emphasize the importance of discourse and social knowledge construction for learning mathematics.

- Mathematical discourse includes focused classroom discussion around mathematical ideas, as well as other forms of communication. Mathematical discourse enables students to develop understanding through constructing, sharing, critiquing, clarifying, and refining their own ideas and those of others. The multimodal nature of mathematical discourse opens possibilities for technology to support this important component of learning math.

- Researchers have identified a number of strategies to support and facilitate meaningful mathematical discourse in classrooms. The five practices for orchestrating classroom discussions (Smith & Stein, 2011) suggest that teachers in whole class contexts anticipate possible student thinking before a lesson, monitor students' mathematical work, select specific students to present their work in a particular sequence, and connect across student work to highlight the math they want students to learn. Math talk moves (Chapin, O'Connor, & Anderson, 2013) offer another strategy for engaging students in partner, small-group, and whole-group discussions about math.

- In contrast to teaching and learning through mathematical discourse in collaborative contexts, individualized instruction is an approach that typically draws from a behaviorist approach to learning. A classic case study in math education (Erlwanger, 1973) highlights a sixth grade student, Benny, who used an individualized curriculum in the 1970s, the goal of which was, "… 'to develop an educational program which is maximally adaptive to the requirements of the individual' Lindvall & Cox, 1970, p. 34)" (p. 88).. Although Benny performed well within the (non technological) program, researchers revealed a number of misunderstandings and error patterns in his mathematical conception of rules and answers. The role of discussion, or lack thereof, is described in the study, "There is never any reason for Benny to participate in a discussion with either his teachers or his peers about what he has learned and what his views are about mathematics. Nevertheless, Benny has his own views about mathematics—its rules and its answers" (Erlwanger, 1973, p. 52). As teachers grapple with incorporating technology-enabled personalized learning programs in modern classrooms, this seminal study offers a precautionary tale about individualized mathematics instruction and the need to balance discourse about concepts with practice of procedures.

Reflecting on Technology in Math Teaching

As you read the cases of Ms. King's and Mr. Lennon's Algebra I classrooms, you should have noticed significant differences in how the math was taught and how technology was used to support their math teaching. In Ms. King's class, she aligned her technology use toward a mathematical goal of comparing linear equations using various representations and a technology goal of more personalized learning to meet individual needs. Mr. Lennon aligned his technology use with the same

content goal, but used technology to facilitate collaboration and discourse to meet and leverage individualized needs and assets. In both cases, we see evidence of alignment between goals and use of technology for teaching and learning math. Ms. King has embraced a technology goal for personalized learning, but acknowledges some concerns resulting from that approach. The way she is using technology for personalized learning does not necessarily align with what research tells us about the nature of learning math. This helps to illustrate that aligning technology use with content goals and technology-use initiatives is important, but tensions can arise when technology use conflicts with what research and theory tell us about teaching and learning math (with or without technology). Table 3.3 compares the cases of Ms. King and Mr. Lennon.

TABLE 3.3 Use of Technology in the Cases of Ms. King and Mr. Lennon

	The Case of Ms. King	**The Case of Mr. Lennon**
What technology is used?	1:1 laptops; online personalized lessons, videos, exercises, and quiz from Khan Academy.	Online card sort through Desmos; online videos, exercises, and quiz from Khan Academy; interactive slides through Desmos.
What math is emphasized?	Comparing linear functions using verbal descriptions, equations, tables, and graphs.	Identifying multiple representations of linear functions, and comparing features of linear functions.
How is the lesson launched?	Ms. King shows a demonstrative video at the beginning of the first class, and then students work independently to progress through two lessons and a quiz.	Mr. Lennon uses Desmos to engage students in a sort of linear functions represented as graphs, tables, equations, and contextual situations. He uses partner talk and class discussion to launch a discussion about linear function representations.
Who is doing the math in this lesson?	Students watch videos that explain comparing linear functions and then complete practice questions and quizzes individually.	Students work with a partner to sort linear function representations in a digital environment, complete Khan Academy online exercises, and compare features of linear functions on Desmos slides.
When and how is technology used in the lesson?	The lesson is almost completely conveyed through personalized learning technology.	Mr. Lennon uses technology to launch the lesson, facilitates student collaboration and discussion through an online card sort, assesses students as they work together, and facilitates discussion and assesses students' understanding at the end of the lesson.

A helpful lens for considering Ms. King's and Mr. Lennon's technology use in these lessons might be to ask: *"How does the use of technology in this lesson align with effective math teaching practices?"* Because the math lesson relies on

technology-enabled pedagogy that runs counter to research and best practices for teaching and learning math, it is not surprising that Ms. King has mixed feelings about the outcomes of her approach.

It is also important to consider the role technology plays in providing equitable access to math learning. Ms. King was motivated, in part, to use technology-enabled personalized learning to meet individualized student needs. Students could work at their own pace to some extent (within the constraints of her scope and sequence), and the arrangement allowed her more one-on-one time to assist students who were struggling. However, she noticed that some of her students had more difficulty focusing during individual computer-based learning, suggesting that the approach did not work the same with all students. Although the methodology enabled some individualized pacing, all students ended up doing the same work in, more or less, the same way.

On the other hand, students in Mr. Lennon's classroom used technology collaboratively throughout the lesson. Students worked together to complete a sorting activity online, and then Mr. Lennon facilitated a classroom discussion based on their technology-enabled work. Even though some student contributions weren't completely correct, Mr. Lennon leveraged all student contributions to highlight important student thinking about linear function representations. To move from recognizing representations to comparing linear functions, he had students complete online practice exercises. In doing so, Mr. Lennon also let students choose which videos and online features they found useful for completing the exercises. Throughout the lesson, all students had an opportunity to use the same technologies in ways that supported collaboration and communication about equivalent fractions.

Recommendations for Practice

This chapter began with the question: *Instead of screens to enable disconnected, individualized learning, what if we leveraged technology to facilitate mathematical discourse and collaboration?* Vignettes from Ms. King's and Mr. Lennon's classrooms show contrasting visions of what these two ideas could look like in secondary classrooms. How can you leverage technology to facilitate mathematical discourse and collaboration? Here are three suggestions with accompanying elaboration and examples.

1. Make sure students have a chance to engage in mathematical discourse during every lesson.

Technology should support communication and collaboration, not replace it. Giving students an opportunity to communicate mathematically lets them know their ideas are worth sharing. A variety of technologies can support sharing. In this case, the teacher used Desmos to facilitate a card sort, and facilitated a math discussion around students' responses. The technology enabled him to easily view all student responses, and to select, sequence, and display student work for discussion. Other tools such as Pear Deck and Near Pod can also elicit student work, but the mathematical capabilities in Desmos make it an attractive option for secondary math teachers. A variety of technologies allow the teacher to display student contributions for class discussion.

You could also use technology to facilitate mathematical communication in nonverbal formats. Through tools such as Google Classroom, Edmodo, or classroom blogs, students can share pictures or written accounts of their mathematical reasoning. Asking students to examine, discuss, or comment on one another's contributions supports the Common Core mathematical practice, MP3. *Construct viable arguments and critique the reasoning of others.*

2. Technology can, and should, support effective teaching practices, but technology won't replace the teacher!

Fill in the blank: "_____ today not only rivals formal education, but better yet, it increasingly is being used to supplement the work of the teacher." Did you guess internet? Computers? Maybe even television? This is the opening sentence of an article entitled, "Radio in the Classroom" from 1942! The tension between technology and teacher in the classroom is nearly a century old, but technology has yet to replace teachers.

Technology can change the role of teachers and students. In this chapter, two vignettes showed how Khan Academy could be used in different ways to support different teacher and student roles. The same could be said of tools such as IXL or DreamBox Learning. Technologies that offer personalized experiences for learners can supplement good classroom instruction without supplanting the teacher. Regardless of what technology a teacher chooses to use, it is important to evaluate how it fits with your teaching practices and reflect on classroom roles. If your teaching is guided by constructivist or sociocultural learning theories, consider how your technology use aligns with your priorities. If students are staring at

isolated screens in a direct transmission model of learning math, reconsider what and how they are expected to learn math.

3. Use technology to facilitate a variety of collaboration structures.

In some contexts, sharing technology is necessary due to limited device availability. In other situations, students have access to 1:1 devices. Whether they share devices or have their own, technology can be used in ways that promote collaboration. Tools such as connected whiteboard apps or G Suite collaborative apps (Docs, Sheets, Slides) enable real-time collaboration on written or visual projects. In a secondary math classroom, students can use digital collaborative spaces to share their thinking in writing or create presentations of their work to share with the class.

Students can also collaborate with partners on shared devices. Working together to solve a card sort in Desmos or to represent a mathematical problem using a virtual manipulative requires both cooperation and communication. You can use videos to pose interesting problems to groups of students who then work collaboratively to find solutions. 3-act tasks from gfletchy.com or Dan Meyer (blog.mrmeyer.com) leverage technology to pose questions that do not require individual devices, but invite collaboration and mathematical discussion. Using technology (interactive whiteboard, projector, screencasts) to select and display student work with interesting tasks can also encourage collaboration and mathematical discussion.

Connecting Cases with Standards

In this chapter, the cases of Ms. King and Mr. Lennon demonstrate ways that technology can be used to teach an Algebra I lesson on comparing linear functions. Following, you will find alignment with Common Core State Standards for Mathematics, as well as ISTE Standards for Students and for Educators. It may be useful to discuss and consider with colleagues how the case aligns with math standards in your state or district, as well as ISTE Standards for Administrators and for Coaches.

Math Content Standard

> **CCSS.MATH.CONTENT.8.FA.2/CCSS.MATH.CONTENT.IF.C9.** Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).

Mathematical Practice Standards

- Make sense of problems and persevere in solving them

- Reason abstractly and quantitatively

- Construct viable arguments and critique the reasoning of others

- Attend to precision

ISTE Standards for Educators

5a. Use technology to create, adapt and personalize learning experiences that foster independent learning and accommodate learner differences and needs.

5b. Design authentic learning activities that align with content area standards and use digital tools and resources to maximize active, deep learning.

6a. Foster a culture where students take ownership of their learning goals and outcomes in both independent and group settings.

6b. Manage the use of technology and student learning strategies in digital platforms, virtual environments, hands-on makerspaces or in the field.

7b. Use technology to design and implement a variety of formative and summative assessments that accommodate learner needs, provide timely feedback to students and inform instruction.

7c. Use assessment data to guide progress and communicate with students, parents and education stakeholders to build student self-direction.

ISTE Standards for Students

1c. Students use technology to seek feedback that informs and improves their practice and to demonstrate their learning in a variety of ways.

4d. Students exhibit a tolerance for ambiguity, perseverance and the capacity to work with open-ended problems.