he fourth vertex is at −3, 2,” suggests one student. William plots
the point on a coordinate grid.
“Oh, no,” interrupts the student
as she sees his work. “I meant −2, 3,” William
erases the point and plots a point at (−2, 3) instead.
“So what kind of quadrilateral is it?”
“It looks like a square.”
“Yeah, it has to be a square, even though it is
tilted.”
“Why is that?”
“Well, it has four right angles, and all of the
sides are congruent.” William marks the diagram,
and the speaker nods in agreement.
“Are you sure they are right angles?” inquires
another student.
“Yes, I checked the slopes.” William takes notes
silently as the speaker continues. “They are either
5 or −1/5, so they are negative reciprocals. That
means they make 90° angles.”
“Oh, and the sides are parallel, too … the ones
with the same slope.” William begins marking the
sides with the symbol >.
“I don't think that's right,” says a student, referring
to the markings on the diagram. “You need a
different symbol.” William changes two of the sym-
boils to >>. “Yeah, like that.”
“Are you sure that the sides are congruent?”
“From 4 to 1 it is down 1 unit and right 5 units,”
a student begins, “and from 3 to 2 it is down 1 and
right 5, so I think they are the same length.”
“Yeah, we could find the lengths using the
Pythagorean theorem.”
“We don’t have to, though. We already know
they are congruent, even if we don’t know their
exact lengths.”
The conversation continues with students seated at tables facing one another. Students in this class expect to talk about mathematical problems like this one and do so regularly. An observer might note a similar interaction in any inquiry-based geometry course. Yet there is an important difference: Here, technology is central to the discussion.

William is not the teacher but a student in the class sitting among his peers. Rather than a pencil, he holds a digital stylus; in front of him, a Tablet PC replaces a paper notebook. Through a classroom projector, his writing on the tablet is immediately visible to everyone in the room. During this class meeting he is serving as "scribe," a role he will pass on to another student the next day. William's notes, like the rest of the notes in the class's OneNote® notebook, are available to other students through the school's computer network. The Tablet PC enables this novel instructional approach.

Different from a traditional laptop, a Tablet PC uses digital ink technology. Originally, digital ink referred to pictures and art scanned into computers for animation. More recently, however, the term has broadened to include writing captured by interactive whiteboards (IWBs) and pen-based computers, including personal digital assistants and Tablet PCs. Although IWBs have filtered through education, Tablet PCs are still uncommon. As a result, the instructional implications of the Tablet PC's unique capabilities remain underinvestigated.

In this article, I present one instructional strategy—scribing—tailored to the Tablet PC (see fig. 1). I illustrate the role of the scribe during discussion through two classroom examples: generalizing the polygon sum theorem and proving the third angle theorem. Then I analyze scribining as an...
instructional strategy as well as students' reflections on their experiences with scribing.

**CASE 1: THE POLYGON SUM THEOREM**

The class convenes as a group following independent investigation of the angle measures of polygons using The Geometer's Sketchpad®. As the discussion begins, the scribe opens a OneNote page containing only typed headings and three polygon diagrams (see fig. 2a).

Students begin by sharing the sums they found for the measures of the interior angles, a discussion that quickly leads to the two versions of the polygon sum formula shown. At this point, the class notes contain only the degree measurements and formulas; these do not stand out in the final version. Next, to build intuition for the polygon sum theorem, students consider the number of diagonals that can be drawn from one vertex in a convex polygon. A student quips, “That’s obvious. It just increases by 1 each time,” and suggests counting the total number of diagonals that can be drawn instead. The class agrees to pursue this more interesting problem, and, to accommodate the discussion, the scribe creates a table and adds the headings “Sum of interior ∡s” and “# of interior diagonals.” The notes so far reflect both the class’s interest and the scribe’s organizational sense.

“I think it would help to see the hexagon,” a student suggests, trying to imagine the number of diagonals it would contain. Without further discussion, the scribe draws the hexagon, including the diagonals. All the students count the number of diagonals in the scribe’s sketch, and several students draw a hexagon themselves to check the scribe’s work. Soon various students comment on the pattern, some of which the scribe chooses to record. One student suggests a closed-form rule. Deeming the suggestion particularly notable, the scribe records and boxes the formula. Other stu-
dents check that the formula truly represents the pattern. Once the class agrees, the scribe christens the formula “Sunghee’s equation.”

Although the notes in their final version (see fig. 2b) suggest a linear record, they actually developed through a dynamic, iterative process. Only after students fully considered Sunghee’s equation, for example, did the discussion turn to the exterior angles or did the scribe add a third column to the table on the Tablet PC. As various ideas surfaced, the scribe scrolled back and forth through several IWBs’ worth of material. The ability to save and review material facilitates discussion, and doing so is effortless with a Tablet PC.

CASE 2: THE THIRD ANGLE THEOREM
Scribing enhances discussions about proof as well as student discovery. The third angle theorem, an early proof in many geometry courses, provides a representative example. Because it is a direct corollary of the triangle sum theorem, a proof of the third angle theorem is accessible to most students, including those lacking experience with formal proof. As students begin the proof, they agree on the given information and how to mark the diagram. A student then suggests the equation that the scribe labeled 2 (see fig. 3a). Another student asks how we could have that, and the discussion pauses while students ponder the question.

During the brief interlude, the scribe adds the “bridge” graphic. (The class had recently likened writing a proof to building a bridge; this step, a student suggested, seems too familiar from the “given” information.) Soon another student speaks up “Isn’t it just the definition of congruence?” After some elaboration, the class feels confident that statement 2 has been proved, and the scribe moves it to step 3. Further discussion leads to the full proof.

This proof of the triangle sum theorem represents the collaborative effort of the entire class. Notably, the style of the proof depends entirely on the students—everything—from the notation to the organization and graphics—was written by the student scribe and vetted by the class in real time. Because it is a student (not a teacher) who holds the pen, whether or not to accept a statement as written necessarily becomes a community decision, independent of the teacher’s authority. The scribe’s sense of empowerment—and that of the entire class—is palpable as students’ ideas are taken seriously and become part of the “official” record.

In pursuing a proof, two classes would not be expected to follow identical paths, nor would two scribes be expected to record ideas in the same way, even for a simple corollary such as the third angle theorem. For comparison, figure 3b presents the proof created by a second geometry class. In this class, early in the construction of the proof, a student suggested an unusual step: “We can subtract to get the measure of angle C alone on one side.”
The suggestion surprised me because I assumed that students would substitute using the equations in lines 3 and 4. Consequently, I would have struggled to write the student’s idea as intended. The scribe, however, understood what the student meant and rewrote both equations to produce lines 5 and 6 in the proof. Other students agreed that these steps were valid. For some students, seeing the rewritten equations clarified the subsequent steps.

In this case, the scribe correctly interpreted the student’s strategy, even though it was surprising to me. If I had been the scribe, my surprise might have signaled that the student’s strategy was “wrong” and thus might have curtailed the class’s evaluation of the idea. Moreover, had I recorded the student’s idea incorrectly, the student would be unlikely to correct me; unavoidably, notes written by a teacher gain an air of authority. In contrast, when the scribe is a student, speakers routinely clarify statements and correct misinterpretations. Further, students sometimes make direct suggestions such as, “Hey, I think you should write that [my idea] down.” I have never heard a student make a similar request of a teacher.

**SCRIBING AS PEDAGOGY**

As an instructional strategy, scribing complements whole-class discussion. In a mathematics classroom, whole-class discussion aligns with the Communication Standard outlined in *Principles and Standards for School Mathematics* (NCTM 2000), which recommends that students have frequent opportunities to talk and write about mathematics. Chapin, O’Connor, and Anderson (2003) advocate whole-class discussion in mathematics and describe several specific benefits of mathematical talk, including these:

- Revealing students’ thinking, understanding, and misconceptions
- Encouraging students to use precise mathematical language
- Deepening students’ understanding of concepts and procedures
- Motivating students to clarify and reflect on their ideas

Combining discussion with scribing amplifies these benefits.

Most noticeably, the scribe’s thinking is continuously on display. In the context of a class discussion, the scribe’s flexibility with mathematical concepts is regularly tested. One student reflected, “Being scribe helped me because you have to understand other people’s thinking and not just [how] to solve a problem.” As another student put it, “You have to write down different opinions and methods, and to write those down you need to understand first.”

Consistent with their charge, students perceived scribing as a solemn responsibility and took the role seriously. “If you’re the scribe,” one student wrote, “You need to focus on what you are doing, communicating with others, and writing down so it’s easier for everyone in the class to understand.”

Scribing also provides a unique way for students to share their thinking—not only the finished product but also the process. They themselves say it best:

- “I like having others scribe because I get the opportunity to see how others think and learn a lot from it.”
- “When others were being scribes, it was very interesting to see how others think and work. It was also interesting to see other people analyzing the same data differently.”
- “When I scribed, it automatically made me concentrate more, especially on other people’s ideas by writing it.”

Notably, reticent students often thrived as scribes. As one quiet student explained, “Scribing allowed me to contribute to the class although I am not as comfortable [discussing ideas] as my classmates.”

Strong mathematics students are able to translate, organize, and even add ideas suggested by others. These students recognize mathematically salient points and select organizational strategies that emphasize relationships among concepts. Weaker students, in contrast, may misinterpret suggestions or record ideas using inappropriate notation. Although the class was generally patient and supportive, scribing errors frustrated some students. One student noted diplomatically, “I just feel when someone who is not sure of our material is scribe, there is an inconvenience.” Another was more direct: “When another student did not understand a question while being a scribe, I was sometimes annoyed by the fact that the class was being slowed down because of one person.”

Because the scribe plays a central role during the discussion, the difference between a talented and a mediocre scribe can be substantial. However, just as weaker students should not be silenced during discussions, they should not be ruled out as scribes. In fact, with appropriate scaffolding, lower-level students can serve effectively as scribes. Such scaf-
folding may include using note-taking templates, previewing the problems that will be discussed, or scribing only during more structured discussions. By giving thoughtful consideration to who will scribe for a particular discussion, the teacher can circumvent some of these problems.

Whether the scribe is at the top or the bottom of the class, the other students will heavily scrutinize the scribe’s writing. Students take responsibility for evaluating the form and content of the scribe’s notes far more than they do for a speaker’s notes. As a result, all students are more focused and attentive. As one student commented, “I think scribing really involves students.” Of course, as one student explained, the effect is greatest for the scribe: “I like being scribe because I feel I always have to be into class, and I automatically get all of the information.” Another added, “[Scribing] helps the way I learn because everyone is always critiquing my work.” For the scribe, the constant attention can also create apprehension. “Scribing was personally really frightening,” one student noted. “Everyone was looking at my writing and drawing, and it made me really stressful.” Still, the same student later reflected that “scribing was fun.” Several other students echoed this person’s apprehension, but they also agreed overwhelmingly that scribing was enjoyable. In fact, although I did not require students to scribe, all my geometry students volunteered to scribe more than once during the course. Moreover, students ultimately expressed increased confidence in their abilities after scribing and were glad that they had volunteered.

Beyond buoying students’ confidence, discussion with scribing also provides authentic reasons for students to learn vocabulary and mathematical conventions. Students learn geometric terms, for example, so that they can express their ideas during discussions; they learn geometric notation and sketching techniques so that they can record their own and others’ ideas when scribing. To be understood by their peers, students strive to express themselves clearly and precisely. They receive immediate feedback as well. The scribe must understand students’ ideas, or these ideas will not be recorded as intended. Recognizing this responsibility, students who serve as scribe are motivated to prepare.

As with any whole-class discussion, while a student scribes, the teacher acts as a moderator to ensure that all students contribute to the conversation. The teacher may use various strategies, such as calling on students to restate one another’s claims, asking students to agree or disagree with previous speakers, or choosing a student to summarize the argument (Chapin, O’Connor, and Anderson 2003). Although only one student scribes at a time, all students attend to the conversation and respond to others when asked to do so.

Teachers without access to a Tablet PC may realize many benefits of scribing by using IWBs or even by simply handing the chalk to a student during a discussion. However, these approaches have their inconveniences. When using a tablet, the scribe remains among his or her peers, thus keeping the focus on the mathematics rather than on the scribe. Moreover, students who would shrink from standing at the board during an extended discussion are often eager to scribe from the safety of their seats. Also, whereas a scribe at the board often stands in front of the notes while writing, no one’s view is ever obstructed when a scribe uses a tablet. Similarly, because writing on a tablet mimics writing on paper, notes are neater and more legible than notes written on a board. Considering these social and practical advantages, a Tablet PC is the ideal complement to scribing.

CONCLUSION
Scribing extends the potential of whole-class discussion, and the added benefits of scribing depend on technology. With a tablet, scribing produces a permanent digital record that can be reviewed at any time. Students take ownership of the mathematics as their ideas become part of the official record, which they literally write themselves. Students focus on the ideas rather than on the speaker, the scribe, or the teacher. In addition, by shifting responsibility to students, scribing motivates all students to deepen their understanding of concepts, facts, and procedures.

Scribing naturally encourages students to talk to one another rather than to the teacher, requires them to clarify their thinking, and provides immediate feedback. Like discussion, scribing can be challenging, even stressful, yet it nevertheless captures students’ interest and builds their confidence. In the succinct words of a ninth grader, “Scribing is a good way for us to learn. It’s pretty cool and fun.”

REFERENCES


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