Formative Assessment through Think Alouds

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Abstract

We describe how teachers used a formative assessment approach called whole class think alouds, which may happen at any time during everyday instruction and foster evidence-based instructional practices. They allow students to collaborate and orally communicate their problem solving with a goal of assessing to promote learning.

Imagine a pair of fourth-grade student who worked collaboratively on the mathematics problem seen in figure 1. Do you wonder what they were thinking while they were problem solving? What do you think they said to each other while they were working?

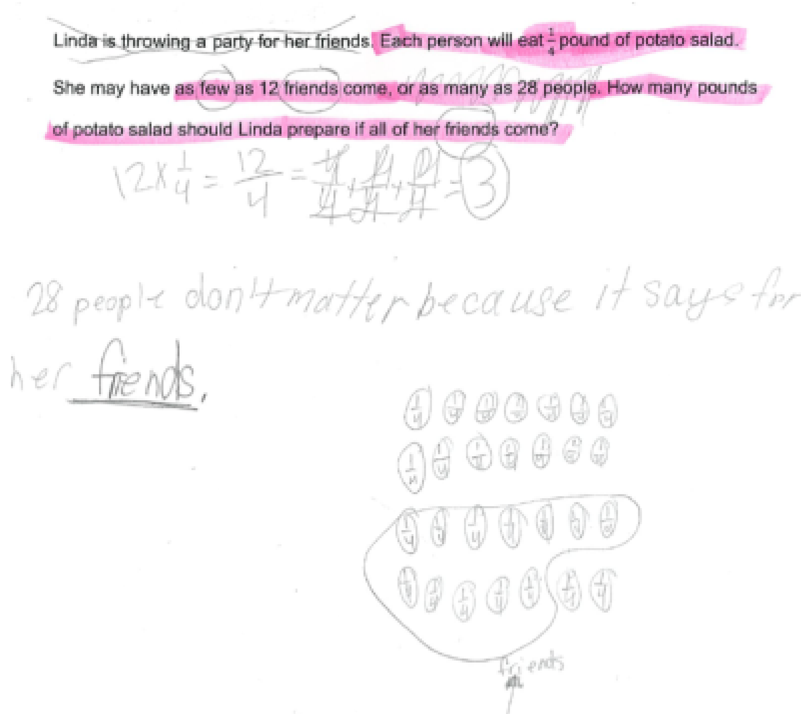


Figure 1. *These two students' were problem solving during a whole-class think aloud (WCTA).*

High quality formative assessments are necessary to monitor students' progress towards learning targets and foster deep mathematics learning (NCTM, 2007, 2014). Mathematics standards such as the Common Core State Standards for Mathematics address problem solving in the Standards for Mathematics Content for every grade level (e.g., "Solve word problems involving multiplication of a fraction by a whole number", 4.NF.4c), as well as in the K-12 Standards for Mathematical Practice (National Governors Association Center for Best Practices [NGA Center] and Council of Chief State School Officers [CCSSO], 2010). Because of thisprofound and consistent emphasis on problem solving, formative assessments should mirror this focus. We share a formative assessment technique called Whole-Class Think Alouds (WCTAs) that teachers can use during problem-solving instruction.

Math Problems and Think Alouds

We often use mathematics problems during instruction as a means to promote problem solving and in turn, address important content and practice standards (see NGA Center & CCSSO, 2010). Mathematics problems are tasks that encourage critical thinking, may have multiple solutions, and can be solved using multiple developmentally appropriate strategies (Schoenfeld, 2011). Problems differ from exercises; the latter are intended to help students gain efficiency with a specific strategy. If mathematics problems and problem solving are part of instruction, then logically, we should also use assessments that include problems to make decisions that foster students' problem solving (Black & Wiliam, 1998). One formative assessment technique that can be easily implemented during instruction is a think aloud.

Think alouds usually include a teacher or education professional and one student. They are "brief and informal conversations between the teacher and an individual…that provide a glimpse into student thinking" (Fennell et al., 2017, p.47). The student reads a problem and explains their thinking aloud to a teacher who takes notes about the student's problem solving. One-on-one think alouds have been used for decades as classroom assessment strategies (Fennell et al., 2017). While powerful, 1-1 think alouds pull the teacher away from other students in the classroom and can be difficult to implement. We wanted an alternative to 1-1 think alouds to formatively assess students' problem solving in a quick and effective manner during everyday instruction.

What is a Whole Class Think Aloud?

A whole-class think aloud (WCTA) uses the same principles as a 1-1 think aloud but expands it to include the whole class simultaneously engaging in paired think alouds for a single task. Figure 2 provides a synopsis to implement a WCTA. Students work collaboratively, in pairs, on a single mathematics problem. They are encouraged to write their ideas and rough draft talk with their partner while problem solving. Rough draft thinking shared aloud is unpolished and raw (Jansen, 2020), yet highly powerful as formative assessment data. The teacher circulates throughout the room during the WCTA making observations that attend to ways that students (a) read and interpret the problem, (b) employ strategies to solve it, and (c) reach a solution. Teachers make notes about what students say and do as evidence to inform their future instruction. The entire process takes about five minutes and can be implemented at any time during a lesson. <insert figure 2>

Figure 2. *This is the five-step process to implement Whole-Class Think Alouds.*

Implementing Whole Class Think Alouds

Background

We partnered with four mathematics teachers from two school districts – one rural and one suburban – to do action research. These teachers were involved in a project developing problem-solving tests that addressed grades 3-8 Common Core State Standards for Mathematics (Bostic et al., 2021), which are called the Problem Solving Measures (PSMs). Teachers and us were excited to use word problems like those seen on the PSMs. Figure 1 shows a PSM4 item addressing Number and Fractions (NGA Center & CCSSO, 2010) content.

Preparing and Implementing WCTAs

Teachers selected two or three problems from their curricular materials, or other resources that aligned with their instructional need for each WCTA. They used the sample PSM4 item as an example for aspects of word problems that might be suitable for WCTAs. Those aspects included the task being a word problem that connected to instructional content and practice standards, stimulated critical thinking, might be solved in multiple developmentally appropriate ways, and may or may not have multiple solutions.

Teachers purposefully placed students in pairs based on ease of working with others. Students were encouraged to explain their thinking aloud to their peer and collaborate during problem solving. A problem was given to students and then chorally read aloud as a class. The classroom teacher intently observed students' work, actively listened to students' ideas, and took notes about students' problem solving (see Fennell et. al, 2017, pp. 32-38 for observation templates that can be adapted). The extent of support necessary for implementing WCTAs was minimal, requiring no off-contract time or extended professional development. We interviewed teachers regarding their experience with WCTAs.

Teachers implementing WCTAs keenly focused on the ways that students represented their ideas while problem solving, the mathematical language used while discussing the problem, and how students contextualized their work during and after problem solving. Such language provided evidence about how students were decontextualizing the problem situation into mathematical representations and later, how students contextualized their results for the problem situation. These student data provided indicators about *how* and *the degree to* which students engaged in the second Standard for Mathematical Practice: Reason abstractly and quantitatively (NGA Center and CCSSO, 2010). Teachers used note-taking tools like the one seen in figure 3 to document students' mathematical thinking.

Focus of the WCTA:	Brief description of potential solution strategies:

Student Name:	Thinking observed:	Misconception observed:

Figure 3. *This is a note-taking tool for use during whole-class think alouds.*

Teachers noted strategy use as well as any misconceptions that students voiced or showed. For the problem in figure 1, teachers listened to students' thinking about how they interpreted the language "as few as" or "as many as" into a mathematical representation.

What Did We Learn?

WCTAs Inform Mathematics Instruction

WCTAs provided teachers with an opportunity to actively listen to students' problem-solving approaches and misconceptions in relation to a specific concept. This in turn had potential to influence future problem-solving instruction. Maria, a fourth-grade teacher, shared after a WCTA, "… because they [students] are talking and you're hearing what they're saying… and I see [their work] firsthand." Actively listening to and observing students' problem solving positioned teachers like Maria, to be intentional listeners. She added, "it [actively listening] is hard for me. I'm going to be honest. There are not a lot of times [during everyday instruction] where I'm walking around taking notes on what they're struggling with".

Teachers frequently shared that they do not usually intentionally listen to students' thinking in the same way as they did during WCTAs. They expressed feeling various external and internal pressures that stopped them from using instructional time to listen and watch students' problem solving. One of those pressures was to gather assessment data from students but rarely had time to reflect on those data. Some shared that they felt a strong push to move to the next part of a lesson because as Maria noted, "I am expected to strictly follow the pacing guide...but whole class think alouds are assessments. I don't feel like I'm losing instructional time like if I gave a written quiz that would require time to grade. Even as the think alouds are happening, I'm planning what I want to do next". WCTAs helped teachers address the pressures to assess student learning, use those WCTA data to inform instruction, and feel that they were not losing time to teach.

The teachers who implemented WCTAs communicated that they regularly used formative assessment such as quizzes, homework, and exit tickets; yet, they also expressed not having formative assessment techniques that allowed them to attend to students' real-time work in the moment in the same manner as WCTAs. Another fourth-grade teacher, Maddie, shared that she usd exit tickets fairly often: "Exit tickets are helpful but for the same amount of time, I'm getting more and richer information from them [WCTAs] about students' problem solving." With exit tickets, teachers must take the time, often outside of class, to review each student's response. They also require students to communicate in writing, which can be a barrier for some students. WCTAs, however, provided teachers with immediate feedback. Maddie said that "I can listen to students' work and see their problem solving in real-time with whole class think alouds. Sometimes what students say doesn't come through in their written work." The students' raw and unpolished rough draft work gave teachers direct access to students' current ideas and misconceptions, especially the ways in which they dealt with the mathematics within a problem situation. Teachers were able to hear each step of a student's thinking process during a WCTA, which they may not necessarily gain through an exit ticket. Offering students opportunities to problem solve in spoken and written language provides better access for them to express their thinking and addresses the Universal Design for Learning Principle of multiple means of action and expression (CAST, 2018). Offering students multiple ways to communicate their thinking increases access to the mathematics content and further engaged them in the mathematical practices (NGA Center and CCSSO, 2010).

WCTA data compelled teachers to modify their instruction because they had new data about students' current understanding and misconceptions. They expressed confidence that WCTA data accurately conveyed what students knew and were able to do. For example, Maria chose a problem that assessed students' ability to use their knowledge of perimeter and area while problem solving as part of a WCTA (see figure 4).

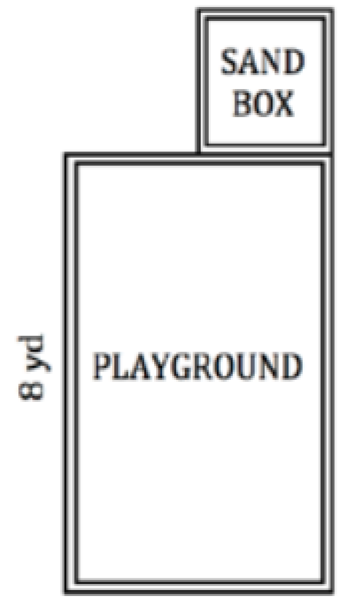
Name: ______________________________ Date: ______________

4.MD.3

The park in Alyssa's neighborhood had new equipment and play areas added. The picture to the right shows part of the new park.

The new playground space has a length of 8 yards and an area of 48 square yards. Attached to the playground is a square sandbox. The width of the sandbox is half the width of the playrgound.

Alyssa was wondering about the area of the sandbox. Use the space below to show the steps that Alyssa could follow to find the area of the sandbox. Fill in the blank at the bottom of the page with the correct area.



Area of the sand box: ______________________________________

Figure 4. *This fourth-grade problem addresses measurement and data content. standards*

Maria was interested in learning about students' thinking related to their knowledge of two mathematical structures (i.e., area and perimeter). She knew from prior experience that these topics often gave students substantial struggle. Shortly after this WCTA, Maria said "I saw that students can plug values into an equation but struggled to make sense of the problem. I want to provide them something that helps them [students] see their misconceptions so we can move forward in our geometry unit." Use of the WCTA data guided Maria to reorient her instruction to meet students' needs beyond substituting values into a known formula. Maria added that "The WCTA data helped me reflect on what my students' *could do*, which was different from what I was seeing on their homework from the night before, which focused on what they could *not do*." By the end of the WCTA, Maria learned that her students were able to make sense of the concept of area, but struggled with its application. She used these data from the WCTA to plan the next day's lesson where students applied the concept of area to different scenarios.

Better alignment between assessment and instruction

In many WCTAs, teachers noticed that students' responses matched what was anticipated, which led to confidence that teachers' assessment and instructional practices aligned with desired objectives. There were some instances that the problem used during the WCTA seemed to highlight important considerations. One problem from a WCTA and two students' work on it, which was not anticipated, is shown in figure 1. The learning target for the task shown was to assess students' ability to "solve word problems involving multiplication of a fraction by a whole number" (NGA Center and CCSSO, 2010, p. 30, 4.NF.4.C).

An anticipated student outcome was for students to reason about how Linda accounts for the largest number of possible guests. Maddie expected students to multiply 28 by $\frac{1}{4}$. Maddie listened to her students' thinking and heard that the terms "friends" and "people" in the task gave students troubles while problem solving. She noticed students perceived "friends" and "people" as different groups. Other formative assessments that Maddie used, had not provided her an opportunity to notice how students read and interpret mathematical text into mathematical representations like expressions or pictures. Her focus was typically on helping students execute mathematical procedures correctly, not helping them interpret texts in word problems. Ultimately, Maddie revised her future instruction to support students' comprehension of mathematical text. Maddie also taught English Language Arts, so drawing on these new data helped her to bridge mathematics and English Language Arts instruction in ways that promote literacy across the content areas.

WCTAs feel natural

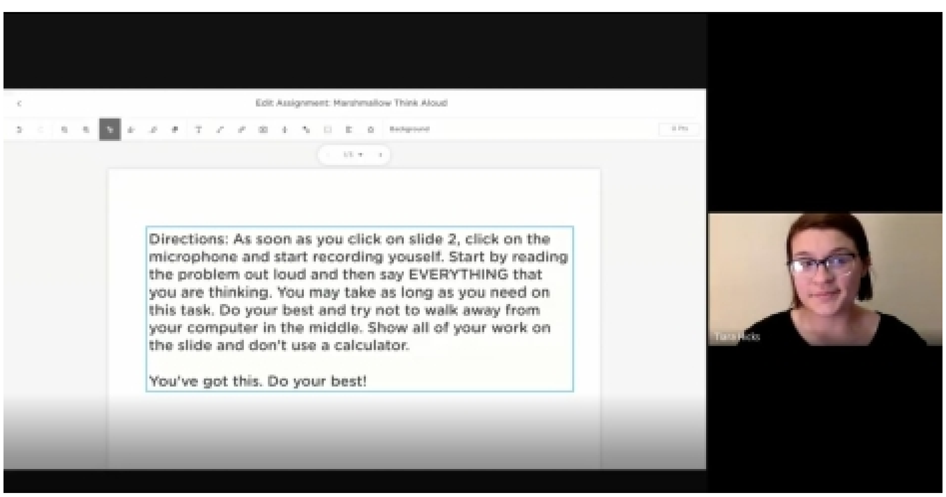
Immediately following the first WCTAs, Maddie and Noah, another teacher on the fourth-grade team, asked their students how they felt about working during the WCTA. Students overwhelmingly communicated that they enjoyed the opportunity to talk with a partner and that it felt very natural. One student's comment was typical of peers: "I was able to talk to my partner when I was stuck and that helped me." In another class, Noah had a student who was often cared about finding a single strategy to solve a problem. During a WCTA, the student was able to see his partner's perspective. Noah commented about this particular student:

> He, at first, did not want to listen to what the other student had to say. Personally, I often have to really expand his classmates' thinking so that he can see it in another way. In this case, he [the student] worked to understand how his partner was thinking. When I asked him what was different about WCTAs, he told me that he was 'just talking about math' with his peer.

This example highlights how one student sought to understand a peer's perspective that was different from his own because the student perceived it as a conversation – he was "just talking about math". WCTAs allowed for Maddie, Noah, Maria, and other teachers implementing WCTAs to equitably attend to students' ideas in the room. Teachers and students communicated that WCTAs felt like conversations about mathematics.

Using WCTAs in Your Classroom

We believe that there may be individual differences in how WCTAs are implemented based on preferences and pedagogy of a teacher, local classroom contexts, as well as the content area. Tiara (Tia) Hicks is a middle grades teacher who continues to use WCTAs and even did so during online instruction during the 2020-2021 academic year. You can learn more implementing WCTAs in video 1. The way you conduct WCTAs depends on student differences, cognitive development in different grade levels, and cultural contexts. While WCTAs were implemented during mathematics lessons in grades 3-6 for this action research, we believe that WCTAs have potential for teachers in other grade levels or other content areas. We share a few strategies to implement WCTAs in your classroom based upon what we learned working with teachers.



Video 1. Tia Hicks (first author) describes using whole-class think alouds in an online environment.

Preparing to use WCTAs

Establish classroom norms that describe how students do math together. This is relevant for both in-person and online instruction. One norm visible in participating classrooms was “We will encourage one another to share ideas”. A second norm was that “Mathematical ideas do not necessarily need to be polished or perfect to be shared with others.” Students need to feel safe and supported during a WCTA because establishing such norms gives them freedom to say everything they are thinking without fear of failure.

When selecting both the number and the content of the problems, consider what you intend to assess (i.e., learning objective). For example, you may want to assess students’ problem solving in ways that integrates multiple content areas or multiple content standards. Prior to conducting any WCTA, think through the viable strategies that your students might use while problem solving as well as possible misconceptions.

Implementing WCTAs

WCTAs can be conducted at any point during a class period, as an initial task, middle of a lesson, or near the end of instruction. WCTAs bear many similarities to the monitoring practice described by Smith and Stein (2011) but there are two distinct differences. First, a goal of WCTAs is to assess students’ problem solving, mathematical skills, and conceptual understanding. Second, the teacher ends the WCTA peer-to-peer discussions and uses those data to inform future instruction.

Before beginning a WCTA, tell students that they will be working with a partner to solve a problem and that they should communicate their thinking aloud to a partner so the peer can understand it. Explain that you will walk around the class observing and take notes on their thinking, will not assist them during problem solving, and there are no grades attached to WCTA work. Finally, encourage students to re-read the problem and read it aloud. You might direct students to draw pictures about the problem if they feel stuck. In Tia’s online instruction, students sometimes expressed feeling stuck with a problem, then drew pictures, which seemed to help them move past that feeling. This is further evidence of their engagement in SMP#2, reason abstractly and quantitatively (NGA Center and CCSSO, 2010).

To start a WCTA, the class might chorally read the problem together. Tia and the fourth-grade teachers noticed that choral reading was helpful. While students engage in the WCTA, take notes on students' problem solving, and not merely whether they solve the problem. The format that you use to record their notes may differ based on the focus and purpose of the WCTA. A note taking tool like the one in figure 3 was helpful to organize the collected data. Figure 5 shows two completed note taking tools after enacting WCTAs.

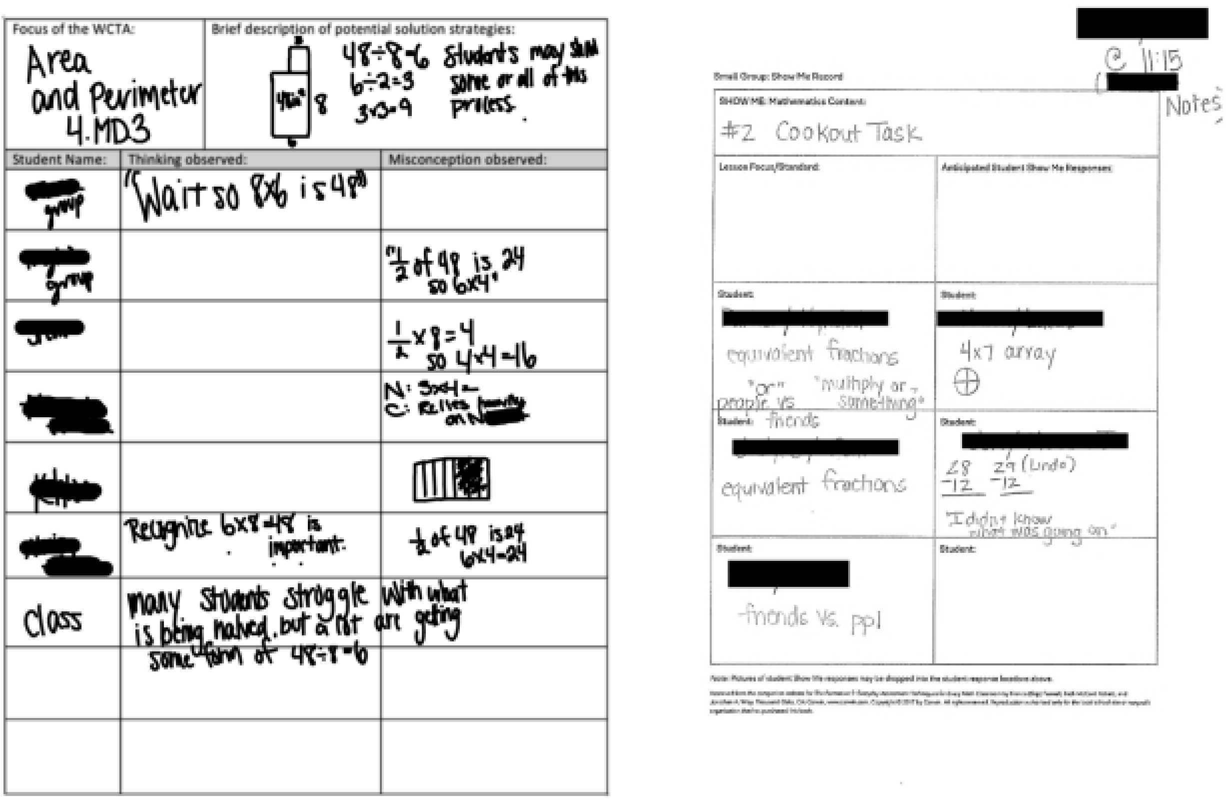


Figure 5. *Teachers' note-taking tools with classroom data from WCTAs*

Finally, you might encourage students who tend to be more quiet than others during the WCTA to share their ideas with probing questions like "<Student name>, what are you thinking about with this problem?" Finally, both Maria and Noah said added that a timer helped students pace themselves while working so that they can arrive at a stopping point, even if they do not have an answer yet.

Responding to WCTA Data

Following a WCTA, think about how you want to use the data that were gathered. Will it inform immediate instruction (i.e., that day or tomorrow) or sometime later in the future? During the WCTA, students may be engaged in content that can be used to introduce new structures and concepts. In that sense, WCTAs may be viewed as a way to initiate teaching through problem solving and engage students in problems drawn from everyday life, their communities, and society (Bostic, 2012/2013; Bostic et al., 2016). If you use WCTAs as a means to inform future instruction, then offer students some form of closure with the WCTA task. Some students who did not find a solution struggled to pull themselves away from the problem. Tia and the teachers in our action research reiterated to students that the WCTA was an opportunity to learn about their mathematical thinking, and how they gained a new understanding of their students' thinking. At the end of a WCTA, Maria, Noah, and Tia thanked students for their perseverance and undertaking in the problem-solving process, which connects to the first Standard for Mathematical Practice (NGA Center and CCSSO, 2010).

Final Thoughts and Implications

WCTAs allow us to collect data about students' problem solving. They provide real-time, raw data that may not have been previously accessed, as we heard from teachers participating in this action research. WCTAs also provide an opportunity to attend to all students' thinking in real time – assessing to promote students' future learning. Teachers like Maddie expressed feeling comfortable attending to each and every student through WCTAs, rather than focusing on one student like in a 1-1 think aloud. By using WCTAs, you may learn both what students know in regards to the content being assessed, as well as how students solve problems and persevere while problem solving. As students talk through the problem, you are likely to learn exactly where your students have difficulties. Students' talk provides us with evidence to consider as we plan future instruction.

When assigning an independent task, students may struggle because of a number of external factors including reading difficulties, or with academic language. WCTAs allow us to recognize these instructional factors and assess students' understanding and knowledge of mathematics content while problem solving. In addition, we have an opportunity to access and honor all students' thinking through WCTAs. A culture of inclusion is fostered when using WCTAs where students recognize their peers' thinking and are able to build upon it. WCTAs naturally fit into instruction because they are built upon students talking to one another about their ideas. They give students the opportunity to problem solve and talk about the mathematics they are learning with a partner, and importantly, they can be implemented in just a few minutes at any point during a lesson.

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