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# ATTENDING AND RESPONDING TO WHAT MATTERS: A PROTOCOL TO ENHANCE MATHEMATICS PEDAGOGY

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*For four years we have invested in improving mathematics teaching at the elementary level. By drawing from diverse research emphases in mathematics education and by considering the impact of lessons in terms of student engagement and performance, we have identified four key elements impacting learning in mathematics. Here, we describe the protocol currently used to structure feedback for teachers in the Math Minds Initiative. The key elements that comprise the protocol are: (1) effective variation, (2) continuous assessment, (3) responsive teaching, and (4) engagement.*

Keywords: Variation Theory of Learning, continuous assessment, mastery learning, intrinsic motivation

## THE PROTOCOL

As part of the Math Minds Initiative, we have used a design-based approach to develop an observation protocol that integrates data from classroom observations with research on formative assessment (Wiliam, 2011), intrinsic motivation (Pink 2011), mastery learning (Guskey, 2010) cognitive load (Clark, Kirschner, & Sweller, 2012), and variation theory (Marton, 2015). The protocol is based on classroom observations spanning four years of weekly, bi-weekly, or monthly observations of 10-15 teachers. Three researchers independently coded a set of 20 videos spanning

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a year of practice with 7 teachers to begin refining and validating our descriptors. Here, we describe the various elements of the protocol: (1) effective variation, (2) visible learning, (3) responsive teaching, and (4) student engagement. We then offer a brief classroom illustration that uses the terms of the protocol to describe a two-part lesson in which one part of the lesson yielded higher levels of both success and engagement. Finally, we discuss the evolution of the protocol as we further refine how we draw attention to each of its key emphases.

## Effective Variation

The international comparison of teaching styles in seven countries did not show a clear pattern of best teaching practices (Hiebert et al, 2003). Instead of focussing on teaching practises, Marton (2015) suggested attending to critical aspects that a learner must discern; this is a necessary condition for learning. We have used the Variation Theory of Learning (Marton, 2015) both as an analytical framework to interpret given lessons and to inform teachers' immediate responses to student feedback at various checkpoints during a lesson. We have found that effective variation respects the limits of working memory identified by Clark, Kirschner, and Sweller (2012), while further offering clear strategies for directing attention toward key ideas: *separation* of key aspects (through contrast), *generalization* (through induction), and *fusion* (through combination).

Because teachers in the project use a supplied resource, many aspects of variation are supported and partially constrained by what is offered in the teachers' guide, prepared slides, and student materials. Teachers, however, must be aware of the distinctions made in the resource so that they can effectively highlight them with students and so that they can effectively adapt the materials to support diverse student needs (*cf.* Metz, Preciado-Babb, Sabbaghan, & Davis, 2017); we discuss this further in the section on responsive teaching.

We have recently begun to use the term “ribboning” to describe the way key lesson elements are separated for attention; this phrase stems from work with teachers to colour-code video-taped recordings of their own lessons according to whether a selected moment involves instruction, assessment, or practice. In doing so, we have found that effective lessons typically resulted in narrow bands of colour that resemble ribbons. In other words, these lessons alternated frequently between drawing attention to important discernments and checking whether students made the intended discernments. This may be contrasted with lessons in which large chunks of information are clustered, either in large instructional chunks or in problems that involve multiple new ideas. For these and other reasons, we distinguish our work from discovery, direct, as well as somewhere-in-between approaches to teaching mathematics (*cf*. Metz, Preciado-Babb, Sabbaghan, Davis, Pinchbeck, & Aljarrah, 2016).

**Visible Learning and Continuous Assessment**

On one level, “visible learning” seems very simple: Make each child’s work visible such that the teacher may offer feedback. Doing so is also key to the forms of mastery learning described by Guskey (2010). Initially, however, we found that assessment during class more often took the form of sampling students, either through volunteered or invited response. Often, this did not provide a good indication of next steps required by those students whose responses were not observed.

“Making learning visible” also begs the question of what it is that needs to be made visible. As we discuss further in the section on variation, we have seen that what teachers ask students to engage in often combines multiple discernments that can become invisible to fluent users. These must be separated to make them visible to the student, which can also make them visible to the teacher (*cf*. Preciado-Babb, Metz, Sabbaghan, & Davis, 2016). Attending to ideas at this scale means assessment must occur frequently within a single lesson; checking in at the end of a lesson, series of lessons, or unit is not sufficient. Doing so informs a form of deliberate practice that emphasizes aspects of performance that can be overlooked in the context of more complex tasks (Christodoulou, 2016).

Continuous assessment does more than provide fine-grained opportunities for feedback from teacher to student; each response also provides feedback from student to teacher, allowing the teacher to make appropriate decisions about next steps. In doing so, there is a strong emphasis on preventing misunderstanding rather than remediating: By starting at a level at which students are capable, they may continuously extend understanding.

In observing teachers, we found that even when teachers made learning visible, they sometimes proceeded without using feedback from students to inform the next steps of the lesson. For this reason, we separate visible learning from responsive teaching.

**Responsive Teaching**

Once all students have been assessed, teachers have the difficult task of deciding what to do next. If students were successful, what next step might press the boundaries of their understanding without overwhelming? If students were unsuccessful, might they return to a place of success, then proceed with a task that helps bridge the known and the unknown? Might the teacher offer a piece of instruction or ask a guiding question that helps address an apparent gap? Might a clearer pattern of variation help draw attention to a key idea that the student has not yet discerned?

Note the contrast this forms with common forms of remediation whereby a teacher supports students in completing multiple steps of complex tasks with which they are struggling (*cf.* Sabbaghan, Preciado-Babb, Metz, & Davis, 2015). If a student does require assistance, we emphasize the importance of following up with a similar task that the student may then complete independently. One of the most poignant messages from the youngest participants was that they liked math best when they *didn't need help*. If only some students are successful, task extensions may be offered to those who are ready, thereby allowing the teacher to bring all students back to a place where they might continue together.

In each of these cases, the goal is for all students to discern key ideas then continuously extend their understanding (see also Preciado-Babb, Metz, Sabbaghan, & Davis, in press): nobody bored, nobody waiting for help.

### Engagement

Engagement serves a different purpose than the first three items in our protocol: Effective variation, visible learning, and responsive teaching all point to teacher actions. Engagement, however, acts more as a means of "global monitoring" of the impact of the lesson on student engagement: Again, are all students given opportunities to both master and continuously extend their understanding? In so doing, each new challenge may be conceived of as an intrinsic reward (Pink, 2011).

## CLASSROOM ILLUSTRATION

Here, we offer a brief example of how the protocol may be used to interpret what is happening in a first-grade classroom. The selected lesson was interesting in that it involved two parts, the first of which was highly successful in terms of student engagement and understanding and the second of which was less so. This allowed a clear contrast that involved the same teacher, same students, same day, and same topic—with dramatically different results.

In the first part of the lesson, the teacher gathered the students on the carpet. She asked them to identify a number pair that made ten. Someone suggested "3+7." She wrote 3 + 7 = 10 on a miniwhiteboard, thus ensuring that everybody was starting with a correct equation. Underneath that, she wrote “3 + 8 = ___,” thus offering a direct juxtaposition of the two number sentences:

3 + 7 = 10

3 + 8 = ___

She drew attention to what had changed and asked students what the new sum would be. She started with sums to ten and then moved to doubles; she also moved from adding one to one of the addends to subtracting one from one addend. Each time she offered a new question, she monitored the responses of all students and used their responses to gauge their readiness to move on. Each time she moved to something new, she told the students that since they were doing so well, she was going to give them a “stumper” and asked them to look closely to see what had changed. In other words, she carefully *ribboned* the pieces she wanted students to notice, assessing each child along the way, adapted her sequence according to the readiness of the students, and drew careful attention to important connections within the lesson and to previous lessons on doubles and making ten.

In the second part of the lesson, the teacher placed a set of laminated cards with equations of the form $a + b =$ ____ on each of the tables in the classroom. Pairs of students were instructed to select a card and write the sum of the two addends. One partner was then to create a variation of the original on the back of the card; they could either add or subtract one from either of the addends. The other partner was to answer the new question. Then they were supposed to switch roles. It turned out that this was much more difficult than the opening set of tasks; most students understood that they could change one addend, but the seemingly simple act of transferring the equation to the back of the card required them to hold the entire equation in their memories; they could no longer see the contrast directly. This made it much more difficult for students to attend to the intended relationship between the two equations. Also, sometimes they did not answer the given question correctly, which of course led to errors in the derived equation. In the initial lesson sequence, the teacher intentionally offered new variations as the students demonstrated their growing understanding; now the starting equations were more random and remained limited by the parameters to add or subtract one to each addend. Some students broke this rule and added more than one, but the receiving partner was not always ready for this extension, particularly since strong students were paired with weaker students. Assessment during this portion of the lesson was largely dependent on students checking one another; the teacher circulated and corrected the mistakes that she noticed, but she could not be with every group all the time. Part-way through this activity, she told students they could write the new equation on the same side as the original; this was helpful for some. However, those ready for a greater challenge were still left practicing more of the same with partners who were not ready to extend further. Perhaps *both* partners would have been ready for greater challenge had the initial approach been gradually extended, say, to include adding or subtracting more than one or to adjusting both addends at once.

The protocol has helped us draw attention to aspects of lessons that impact student understanding and engagement and has thus become a valuable tool to use with teachers, both for planning and feedback.

## IMPLICATIONS AND NEXT STEPS

While observing lessons, we have noticed that it is possible for a teacher to use clear patterns of variation to parse and sequence content, to carefully assess all students, to adapt in response to student feedback, and to maintain strong engagement—all without adequately addressing broader connections within or between lessons. Although doing so is key to strong variation, we have been exploring the possibility of separating variation that is used to introduce new ideas and that which explicitly connects and integrates those ideas. Doing so points to an evolving relationship between teacher and resource; while effective variation can and should be pre-planned to a certain degree, and a strong resource can do much to support this, there is much a teacher can do to draw attention to these connections. Furthermore, what defines effective variation must be based on adaptive response to student feedback, which often means teachers need to create their own examples, either to support struggling learners or to extend work beyond that which is offered.

In working with teachers with the protocol, we have begun to develop models for teaching and for teacher learning. Figure 1 presents an emerging framework that integrates key aspects of the observation protocol in a model that serves these ends. We also include an appendix that we have used with teachers to elaborate each section of the model.

| Ribboning | Monitoring | Adapting | Connecting |
|---|---|---|---|
| Use structured variation to draw attention to potentially novel discernments necessary to a concept. | Ensure every student is able and obligated to provide feedback to the teacher in response to each ribboned query. | Revise/devise tasks, explanations, and other engagements to fit with demonstrated understandings. | Move between “part” and “whole” when ribboning to ensure that learners do not lose sight of the concept(s) under study. |

Figure 1: Math Minds Principles (adapted from Davis, 2016)

Note that here, the protocol’s emphasis on engagement is included with adapting; i.e., if teachers effectively adapt their lessons in response to the needs of both high and low learners, they meet the protocol’s criteria for engagement. Effective variation is essential to each aspect of the model: The planned lesson and task sequence should incorporate clear patterns of variation (both to separate and re-connect), and adaptive response requires further attention to how variation is structured.

In summary, we have found that the ways concepts are broken down, extended and re-connected, the ways attention is drawn to key ideas, the ways each child is assessed, and the ways that information from those assessments are used to inform next steps in a lesson are critical to our work. Moving forward, we plan to involve more observers external to the project in further validating and refining the criteria in our observation protocol. The key ideas of variation (including connections), monitoring, and response, however, have proven effective and stable.

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## Appendix A: Planning for Teaching

Ribboning

Identify critical features. Use contrast to separate and generalize each; ensure that each variation is posed as a question that can be assessed.

- Ensure fluency of requisite knowledge.
- Identify critical features that students need to discern.
- Start somewhere that allows all to engage, then build.
- Select a baseline all can reach, then refer to the rest as bonus.
- Provide clear explanations of what can't be figured out (terminology, background, etc.); do not let volunteer answers to questions substitute for teaching.
- Offer examples and non-examples ("yes – no – also").
- Change only one thing from example to example or task to task.
- Change what you want to draw attention to.
- Name and highlight what you want students to notice.
- Organize to make contrasts obvious; juxtapose to allow easy comparison.
- Avoid visual and auditory clutter (e.g. extraneous teacher talk, cluttered boards, cluttered space).
- Before moving from example to example or task to task, check *each child* for understanding.

Monitoring

Make learning visible by asking questions that highlight each new understanding; assess every child for every idea; use independent mastery as indicator of success.

- Monitor understanding of each key idea; no long segments of talk or practice without checking *each child* for understanding.
- Ask questions that allow the teacher to know whether students have made key discernments; e.g., plotting (1,1) on a Cartesian plane won't tell you whether a student discerns $x$ from $y$.
- Allow time for all to respond; a few extra seconds can make a big difference.
- Attend first to the weakest students.
- Don't rely on self-reports; many won't respond honestly.
- Ensure frequent involvement of all (no lengthy discussions with single kids or long gaps between when any given child has an opportunity to respond / be assessed).
- Avoid overuse of single-child response like hands-up or one student at the board.
- Look for the sense in students' responses; these offer insight into what is needed; also, they may have offered the correct response to the question they thought you asked
- When helpful, gather, juxtapose, and compare/contrast diverse student responses.
- Make students feel like they're scaling mountains: e.g., "I don't think I can make questions any harder than that!" Don't say, "This will be easy."
- Get excited over new insights, even if they seem trivial.
- Aim for *independent mastery*. If a student needed help on a task, offer another.

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| Adapting<br>Decide whether next steps should step back (to address a newly identified critical feature or to strengthen patterns of variation for one that has already been identified), offer further practice (to allow independent mastery), or extend ideas for which students have demonstrated success; consider potential bonus questions for those who are ready to move on before others.<br>If you encounter difficulty, step back, then proceed with a smaller step or a clearer pattern of variation; do not attempt to walk students through tasks that require multiple new discernments.<br>• Contrast errors with correct responses to highlight the source of error.<br>• Fill in instructional gaps as needed.<br>• Continuously extend in clear increments.<br>• Allow enough practice for students to experience independent mastery.<br>• Move quickly.<br>• Include bonuses for all; have extra bonuses for quick finishers. |
| Connecting<br>Vary multiple critical features simultaneously (i.e., fuse); solve problems that combine multiple understandings that have been previously discerned; ask students to extend variation of particular features; ask students to manage variation by working systematically<br>• Ensure separated components are put back together. What is the big idea(s) students should take away from the lesson?<br>• Draw attention to connections (including logical relationships) between key lesson components and between lessons.<br>• After individual variables have been varied one at a time, vary more than one at a time.<br>• Ask students to generate bonus questions (within clear parameters); reflect on what makes them effective / ineffective.<br>• Ask students to solve problems that involve multiple ideas that have been previously discerned.<br>• Teach students to manage variation by working systematically and attending to the patterns and relationships that emerge as they do so. |