Whole Class Discussion in TEFA

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1. Introduction: WCD in TEFA

Whole-class discussion (WCD) is central and indispensable to the Technology Enhanced Formative Assessment (TEFA) method of teaching with a classroom response system (CRS). The use of CRS technology is the most visible aspect of TEFA, but WCD that begins with the CRS histogram display is where the bulk of the teaching and learning actually happens. Or rather, where it should: the outcomes are highly dependent on the characteristics and quality of the WCD.

Orchestrating highly effective WCD is perhaps the most challenging aspect of doing TEFA. WCD is where it "all comes together," placing great demands on the teacher's skills and cognitive resources. Part of the problem is that orchestrating whole-class discourse is not generally represented to teachers as a skill; it is assumed to "just happen" if students are properly motivated, the teacher is properly prepared, etc. Part of the solution, therefore, is to dissect WCD and its role within TEFA, making explicit the objectives it can serve, the ways it can vary, and strategies for making it work. That is the aim of this paper.

Section 2 highlights the under-appreciated role of talk — rich, dialogical discourse — to science and mathematics instruction. Section 3 identifies specific benefits that WCD can yield as a phase of the TEFA "question cycle." Section 4 presents a framework for talking and thinking about discourse and WCD, with the intention of empowering teachers to make choices and changes. Section 5 presents a high-level strategy for managing some of the complexity and cognitive demand of orchestrating WCD that is both authentically spontaneous and dialogical, and also productively instructional. Finally, Section 6 offers a collection of principles, tips, advice, and opinion for making WCD work better. Readers with an aversion to highbrow theory should be reassured that the sections get progressively more concrete and practical through the paper.

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Before we begin, however, a few clarifications, qualifications, and protestations are in order. Sometimes we'll be talking about *discourse*, and sometimes about *whole-class discussion* (WCD). We use the word "discourse" to mean any spoken communication involving two or more people. WCD is a specific kind of discourse, in which a teacher and whole class of students participate together in a single "thread" of conversation, with different people contributing at different times. WCD does not refer to multiple sub-groups within the class carrying on their own conversations, nor to the teacher delivering instructions or content in a monologue. Some portions of this paper will be applicable to discourse in general, while others will address WCD only.

We most emphatically do *not* mean to disparage small-group discussion, individual seat-work, group-work, one-on-one conversations between a teacher and student, or any other "non-frontal" teaching methods. Nor do we mean to imply that lecture, presentation, direct instruction, or other unidirectional communication is always bad. Each has its place within well balanced instruction. Rather, we are asserting that WCD is a vital *part* of the specific pedagogical method called TEFA, and that TEFA can be a powerful *part* of a science or mathematics teacher's repertoire. Much of what we describe below is applicable outside of TEFA, but we are not trying to describe how all teaching should be.

Also, we are not trying to assert that all WCD — or even all WCD within the TEFA question cycle — should look exactly the same in all classes. As the framework in Section 4 attempts to make clear, the nature of discourse can and should vary according to the pedagogical purpose of the moment and the nature of the content under discussion. Further, the ages and backgrounds of the students, the class' general "personality," and other contextual considerations will impact the exact nature of discourse that is realistic and desirable.

Nevertheless, our central tenets hold: that discourse is central to learning science and mathematics; that WCD is a vital part of TEFA; that the characteristics of WCD strongly influence its effectiveness; and that specific thinking tools, strategies, and tips can significantly improve a teacher's ability to foster the kind of discourse they want when they want it.

2. The Importance of Discourse in Science/Math Instruction

Scientific/Mathematical Thinking

We are addressing the importance of discourse and WCD for teaching and learning, but that begs a very important question: learning *what*? We don't mean what specific portion of subject content — linear algebraic equations, for example, or plate tectonics — but rather the *nature* of the learning we want students to acquire. Drilling students on how to solve a particular form of equation when it's staring them in the face, when they know what skills they're supposed to use, when they know exactly what kind of result they're expected to produce, and when they've just solved a half-dozen similar ones is one kind of teaching task. Getting them facile with a toolbox of mathematical ideas and skills for analyzing situations and drawing conclusions is quite another. The instructional techniques and considerations appropriate to each differ greatly. Similarly, one would approach differently the tasks of training physics students to calculate the kinetic energy of an object after falling a set distance and teaching them to argue one side of a lawsuit based on analysis of the physics of a situation.

There is no doubt that teaching students facts and procedures is a necessary part of any science or mathematics instruction; facts and procedures provide the individual tools for higher-level analysis and problem-solving. There is also widespread agreement that teaching scientific or mathematical reasoning, analysis, problem-solving, and real-world application should be prioritized across the middle-school and high-school curriculum, in both science and mathematics. This belief is articulated in multiple places and multiple ways in the *Massachusetts Curriculum Frameworks* for science and mathematics, in the NCTM *Curriculum Focal Points* and *Principles & Standards for School Mathematics*, and in the *National Science Education Standards*. It is also implemented in commercially available, research based curricula such as *Connected Mathematics* {CMP-2006hom} and *Minds•On Physics* {Leonard-1999mmt}. (How well standardized achievement tests such as the MCAS accord with this perspective is a separate and very interesting discussion, but outside our scope here.)

A teacher who tries to apply the ideas in this paper to the teaching of declarative facts and procedural skills will quickly become frustrated. Quite frankly, the teaching of such things in isolation just isn't rich enough to support true dialogical discourse and collective sense-making — unless this teaching is woven into a fabric of other skills, strategies, purposes, applications, and general concepts. Trying to spark thoughtful discussion about a "you know it or you don't" question is most often an exercise in futility.

Yes, classroom response technology can profitably be used to teach facts and process skills. Yes, formative assessment can improve such teaching by providing rapid, guiding feedback to the instructor and students. But despite its name, TEFA is much more than just posing questions and seeing a histogram of responses. It is meant to support the teaching and learning of scientific and mathematical thinking, reasoning, analysis and problem-solving.

Henceforth, when we discuss learning science or mathematics, we are referring to acquiring the capacity for scientific or mathematical thinking that draws on an array of possible information, ideas, and tools.

Learning science/math is learning a social language

What does it mean to "learn science" or "learn math"? Each is more than a collection of facts, tools, and procedures. According to the influential Russian thinker Mikhail Mikhailovich Bakhtin, learning science or mathematics involves learning the *social language* of the discipline. He defines a social language as "a discourse peculiar to a particular stratum of society (professional, age group, etc.) within a given social system at a given time" {Holquist-1981dbw:430}. It is more than just a vocabulary; it is a language, a set of concepts, and ways of thinking. The assemblage of social languages that a person knows comprises a "toolkit" of ways of knowing and thinking {Wertsch-1991vms:93-118}.

One of the reasons that learning science or mathematics can be challenging for many students is that the nature of scientific and mathematical social languages is qualitatively different from the nature of everyday social languages, in both ontological ways (basic assumptions about the nature of the world) and epistemological ways (expectations for the methods, validity, and scope of knowledge) {Mortimer-2003mms:15}. Another reason is that everyday and science/math social languages can view the same phenomena in very different ways, leading to "misconceptions" or "preconceptions" and to a disconnect between real life and "what we learn in the classroom."

From this perspective, the centrality of discourse to science and mathematics learning becomes obvious. One does not learn a language by only reading about it, completing worksheets on it, and answering questions about it. One learns a language by speaking it — haltingly and full of errors at first, and then with increasing fluency — supported by an expert speaker who can correct stumbles, fill in gaps, and provide an example to mimic. The teacher's role can be described as an interpreter and modeler of the social language being learned {Mortimer-2003mms:17}. Discourse is the primary context in which fluency is developed.

Learning means assimilating from the social plane to the individual plane

Another seminal Russian thinker, psychologist Lev Semenovich Vygotsky, has provided us with a complementary perspective on the role of discourse in learning. In Vygotsky's view, ideas are first encountered on a *social plane*, in interpersonal settings, where they are "rehearsed" between people through talk, writing, visualizations, and other modes of communication {Vygotsky-1987tas}.

> As ideas are rehearsed during the social event, each participant is able to reflect on, and make individual sense of, what is being communicated. The words, gestures and images used in the social exchanges provide the very tools needed for individual thinking. Thus, there is a transition from *social* to *individual* planes, whereby the social tools for communication become internalized and provide the means for individual thinking. {Mortimer-2003mms:9-10}

As in Bakhtin's view, discourse is crucial to learning: the artifacts of communication become internalized as the very tools of individual thinking. Bakhtin does not see learning as a transfer of knowledge from a source (teacher, textbook, etc.) to the learner, but rather as a process of individual sense-making. This is a fundamentally *dialogical* process, in which an individual explores and reconciles his or her internal understandings with what is encountered on the social plane. As one of Bakhtin's co-workers put it, "to understand another person's utterance means to orient oneself with respect to it" {Voloshinov-1929mpl:102}.

If we are to help students reconcile their internal understandings with the scientific or mathematical social language being taught, we must elicit those understandings and get them articulated so that they may be collectively explored on the social plane. This implies that efficacious classroom discourse, including WCD, must often be dialogic in character {Nystrand-2003qti}, representing multiple points of view and ways of thinking. As the framework of Section 4 makes clear, *dialogic* and *interactive* are not equivalent.

3. The Many Goals of WCD in TEFA

One iteration of the basic TEFA "question cycle," without extras such as demonstrations or repeated answer collection, consists of the following seven stages:

1. the teacher presents a question to the class;
2. students discuss the question with neighbors or in small groups (or, alternatively, think about it individually);
3. students enter responses into clickers;
4. the teacher displays a histogram of the class' responses;
5. various students offer arguments in favor of various answer choices;
6. the teacher moderates and steers these arguments into WCD about the underlying issues;
7. the teacher offers some appropriate kind of closure, such as a summary, mini-lecture, contextualizing comments, or segue to another question.

In practice, stage 5 tends to slide seamlessly into stage 6, especially with an engaged class accustomed to the instructional mode. Stages 5 and 6 together constitute the WCD portion of the question cycle. Pair or small-group discussion in stage 2 has many considerations and benefits in common with the WCD portion, but we will not directly address it here.

TEFA packs a lot of learning dynamics into a tightly integrated bundle, so most of the stages serve multiple, complementary ends. Let's identify some of the major goals of the WCD stages.

WCD clarifies thought via articulation and externalization

A person's thinking is often fuzzy and incompletely thought out, especially when the person is struggling with new, partially understood ideas. Most of us have had the experience of thinking we understand or "kinda know what we mean" about something until we try to explain it in speech or writing, at which time we realize the pieces don't connect as nicely as they'd seemed to in the forgiving confines of our own head. The act of articulating a proposition, argument, or explanation imposes rigor. It forces us to fill in the gaps, sharpen the vague bits, and clarify how it all fits together. This insight probably motivated E. M. Forster's famous quote from *The Art of Thought* (1926), "How can I tell what I think until I see what I say?"

Both the small-group discussion and WCD components of the TEFA question cycle engage students in the act of articulating their thinking, which — entirely aside from any feedback they might get as a result, and aside from any impact their utterances might make on others — has the benefit of helping to clarify their own thinking and inform them of what they don't understand as well as they thought they did.

WCD lets students confront other ideas and points of view

From a constructivist point of view, learning is not so much a matter of absorbing new knowledge as of evolving, and at times dramatically restructuring, one's knowledge to accommodate new ideas and evidence. Vygotsky argues that this primarily occurs as the individual confronts and makes sense of ideas encountered on the social plane. From a simpler point of view, it seems obvious that unless students begin each new topic as "blank slates," at least two different perspectives must be represented and reconciled for learning to occur: the student's initial perspective and the official, established, or approved perspective to be learned. Learning involves sense-making of a fundamentally dialogic nature, which means that multiple ideas and points of view must be represented.

The WCD portions of the TEFA question cycle are designed to elicit students' different ideas and to provide an opportunity for the instructor to inject additional ideas as necessary, supporting dialogicity. That is why we like to see CRS histograms in which many different responses are represented: it means many different lines of thinking are available for us to elicit and contrast.

WCD promotes reconciling disagreements

Learning requires more, however, than just encountering different ideas, perspectives, and lines of thought. It also requires reconciling them and adjusting one's internalized understanding accordingly. This too is meant to occur during the WCD phase of the question cycle. (Or, more precisely, to begin occurring: complete, deep reconciliation is likely to take more time and multiple overlapping experiences.) When multiple perspectives have been voiced, the natural questions to answer are "How do these disagree," "Which is better or more cogent," and "Why did these people come to different conclusions?" WCD is a forum for thrashing out answers to such questions, to everyone's benefit.

WCD supplies stimuli, context, and tools for individual sense-making

Although instruction is inescapably a social activity built upon discourse, sense-making and learning are in the end a fundamentally personal activity in the mind of each learner. But individual sense-making does not happen in a vacuum: it requires a context, and stimuli to be reconciled. It also requires thinking tools — vocabulary, concepts, procedures, strategies — to carry out the sense-making.

WCD provides an arena in which to access potentially rich contexts, sets of stimuli, and arrays of thinking tools. The question under discussion, detailed and explored and perhaps extended as it is examined, sets the context. The question and all the utterances of the teacher and other students constitute the stimuli to be reconciled with the individual learner's internal ways of thinking. And the language and arguments ventured by the teacher and other students, building on one another, contribute to the tool-set an individual can exploit.

WCD provides practice speaking the "social language" of science/math

Bakhtin's view was that learning science or mathematics can be thought of as developing fluency with a discipline-specific social language. Within the TEFA question cycle, students get to practice speaking this new social language during small-group interactions and again during WCD. During WCD the instructor can scaffold students' attempts to speak this language by correcting errors, confirming successes, issuing reminders, injecting new elements, setting expectations, and modeling such speech.

When we think of WCD as practice with a new language, we can see that independent of any specific insights that may be gleaned or resolutions that may be achieved during the discussion, the practice is valuable in and of itself. We might also infer that the less speaking done by the teacher and the more done by the students, the more practicing that occurs.

4. Thinking and Talking About WCD

A Framework for Analyzing Discourse

Eduardo F. Mortimer and Philip H. Scott, in their book *Meaning Making in Secondary Science Classrooms* {Mortimer-2003mms}, present a framework for describing and analyzing the discourse of teaching. To do this they have synthesized and expanded upon previous work in educational research, sociocultural theory, and discourse analysis. Although they are specifically addressing science instruction, the framework is equally applicable to mathematics instruction, provided that one is attempting to teach integrated mathematical reasoning ability and not just isolated facts and skills.

Mortimer and Scott use the term "scientific story" to mean the perspective, thinking tools, skill set, and vocabulary of the "scientific social language" being taught. We have taken the liberty of generalizing their descriptions to include development of an analogous "mathematical story" in a mathematics class.

They describe their framework as "a tool for analysing and planning science teaching interactions" {Mortimer-2003mms:25}. They stress its value for dissecting discourse after the fact as well as for planning and developing teaching lessons.

The framework identifies five relevant aspects or dimensions of classroom discourse, which address the *focus* of the instruction, the *approach* taken, and the *action* of the discourse, as depicted in Figure 1. In what follows we briefly explain each of the aspects and indicate the range of values it might take on. Readers who wish further explanation are encouraged to read Chapter 3 of Mortimer & Scott's book, of which this section is a terse summary.

1. Teaching Purposes

Instruction is not homogeneous; it spans a sequence of different activities and interactions with different instructional goals. The *teaching purpose* of an interval of classroom discourse is an answer to the question "What purpose(s) is served, with regard to the scientific [or mathematical] story being taught, by this phase of the lesson?" Mortimer and Scott identify six possible purposes:

1. opening up the problem;
2. exploring and working on students' views;
3. introducing and developing the scientific or mathematical story;
4. guiding students to work with this story, and supporting their internalization of it;

5. scaffolding students as they apply and expand their use of this story, and handing over responsibility for its use; and
6. maintaining the ongoing development of the scientific or mathematical story.

Note that "teaching purpose" does not refer to the specific subject matter being addressed, but rather to what stage of the process of dialogical exploration, reconciliation, and internalization is in the cross-hairs.

ASPECT OF ANALYSIS

FOCUS	**1. Teaching purposes**	**2. Content**
APPROACH	3. Communicative approach	
ACTION	**4. Patterns of discourse**	**5. Teacher interventions**

Figure 1: Mortimer and Scott's framework for analyzing and planning science teaching discourse. {After Mortimer-2003mms Fig. 3.1}

2. Content Type

The second aspect of the framework, *content type*, is an answer to the question "What is the nature of the knowledge which the teacher and students are talking about during this phase of the lesson?" (Mortimer and Scott call this aspect simply "content," but we find that label confusing.) It has three sub-dimensions that together characterize the nature of what is being discussed:

- Does the discourse use everyday or scientific/mathematical language and ideas?
- Does the discourse seek description, explanation, or generalization?
- Does the discourse require empirical or theoretical support for propositions?

(There are clearly categories of classroom discourse for which these characterizations are inappropriate, such as talk about procedural aspects of "doing" science or math, or about administrative, management, and organizational issues.)

3. Communicative Approach

The third aspect, *communicative approach*, is the centerpiece of the framework. It is, in our opinion, the most telling and useful dimension to keep in mind when thinking about discourse. The communicative approach of a discourse interval is an answer to the question "How does the teacher work with the students to address the diversity of ideas present in the class during this phase of the lesson?" It has two sub-dimensions representing distinct (but frequently confused) qualities of discourse:

- a continuum from *dialogic* to *authoritative*, and
- a continuum from *interactive* to *non-interactive*.

In *dialogic* discourse, more than one point of view is heard, taken seriously, and explored. *Authoritative* discourse, in contrast, is dominated by one point of view; all utterances are viewed from within it and evaluated accordingly. *Interactive* discourse involves multiple co-participants, whereas *non-interactive* discourse involves one person speaking to one or more passive listeners.

Mortimer and Scott point out that discourse can in exist anywhere in this two-dimensional space, including the "dialogic, non-interactive" and "authoritative, interactive" corners. An example of dialogic, non-interactive discourse would be a teacher summarizing in monologue a range of alternative perspectives that had been developed previously or elsewhere, giving each equal treatment. As an example of authoritative, interactive discourse, consider a discussion in which students contribute statements and questions (either spontaneously or when asked to), but where these questions all address the "desirable" line of thinking the teacher is trying to convey, and where the students' statements are all evaluated on the basis of how correct they are according to that line.

These dimensions are crucial to appreciate when assessing the WCD phase of a TEFA question cycle. Most WCDs are, by definition, interactive, though the degree of interactivity might vary according to what fraction of the speech is by the students, how many students participate, and how often students address each other's utterances. We see more variability along the dialogic/authoritative axis, with examples ranging from "guess what the teacher wants us to say" to "let's all share our personal opinions."

No single point in this space is "best," of course: the communicative approach of discourse should match the teaching purposes of the moment. This idea will be explored more below.

4. Patterns of Discourse

The fourth aspect, *patterns of discourse*, seeks to characterize the sequence and nature of turn-taking between the teacher and students as talk occurs. It answers the question "What are the patterns of interaction that develop in the discourse as teacher and students take turns in classroom talk?"

IRE: One pattern that arises very commonly in classroom discussion is the IRE triad, which stands for "initiation, response, evaluation" {Mehan-1979lls}. It is also called "triadic questioning" {Lemke-1990tsl}. In this pattern, the teacher initiates an interaction, typically by asking a question to the class or to an individual student. A student responds to the teacher, often briefly. The teacher then evaluates the student's response according to some criteria — often correctness according to the scientific/mathematical story, sometimes effort, sometimes commonsense "reasonability" — and confirms or disconfirms the response. The evaluation turn can be subtle: a facial expression or nod, simply re-posing the question if the response was unsatisfactory, echoing the response back to the class if it was acceptable, or restating it with corrections if it was off the mark. Students are highly attuned to approval cues, and are very good at inferring the teacher's evaluation of their statements.

IRE triads often chain together, with the teacher evaluating one response and then initiating another triad within the same utterance; the timing, emphasis, or direction of an initiation can itself communicate the evaluation of a previous response. In our experience, for many of the world's science and mathematics classrooms, IRE triads constitute the vast majority of class "discussions." The communicative approach involved (aspect 3) is usually strongly authoritative and weakly interactive.

IRF and IRFRFRF: Another pattern is the IRF, meaning "initiation, response, feedback." In this case, instead of evaluating a student's response, the teacher provides feedback or elaborates on the response in a way that encourages and assists the student in developing their point of view. This often extends into an IRFRFRF… sequence, where the teacher's responses scaffold a student in developing an argument, position, or perspective. The key difference between IRE and IRF lies in whether the teacher's reply to a student response is backward-looking ("how good was that reply?") or forward-looking ("how can I draw something more or better from that student?"). This pattern is moderately interactive and lends itself to, but does not necessarily imply, dialogicity.

TSS: A third pattern (not mentioned by Mortimer and Scott) is TSS, meaning "teacher, student, student" {Feldman-2007tit}. It refers to a discourse pattern in which a teacher initiates a discussion thread, but then multiple students pick it up and sustain it. (The label "TSS" is used even if more than two students in a row contribute.) In contrast with IRE and IRF, students are now interacting with each other rather than each interacting with the teacher. SSS is similar except that it is initiated by a student, rather than by the teacher. Both reflect a highly interactive approach, which may or may not be highly dialogical depending on the content of the talk.

Fill-the-blanks: This pattern (also not addressed by Mortimer and Scott) exists when a teacher makes declarative sentences, pausing in places and exhorting students to "fill in the blanks" by supplying the correct word or phrase. It represents an extreme, almost pathologically authoritative communicative approach with a thin veneer of interactivity.

Other patterns have been observed and described in discourse analytic literature, but a longer list serves no purpose here. Our primary point is that attending to the order and relationship of the teacher's and students' turns in a discussion can be analytically and diagnostically revealing.

5. Teacher Interventions

If students sit in a classroom and discuss freely and the teacher never says or does anything, the students might enjoy themselves, but they probably wouldn't progress much towards an understanding of the scientific or mathematical story they are supposed to be learning. *Teacher interventions* is the framework aspect answering the question "How does the teacher intervene, at this point in the lesson, to develop the scientific [or mathematical] story and make it available to all students?" Mortimer and Scott have identified six forms of teacher intervention in classroom discourse:

1. shaping ideas,
2. selecting ideas,
3. marking key ideas,
4. sharing ideas,
5. checking student understanding, and
6. reviewing.

An intervention in any one of these forms may be effective, ineffective, or counterproductive depending on when and how it is executed.

The Rhythm of Classroom Talk

A well-designed lesson will likely be comprised of several parts — distinct activities or phases — that move through a progression of *teaching purposes* (aspect 1). After opening up the problem, the teacher will explore students' initial knowledge and thoughts, and then shape and build upon these as necessary to develop and help students make sense of, internalize, and become facile with the scientific or mathematical story. Throughout this progression, the *content type* of the parts (the nature of the knowledge addressed) will vary along the sub-dimensions described in aspect 2: sometimes using everyday language, sometimes formal scientific/mathematical; sometimes describing, sometimes seeking explanation, sometimes generalizing ideas.

The teacher's chosen *communicative approach* (aspect 3) will vary as well, probably beginning as highly interactive and dialogical to explore the topic and students' thinking, becoming interactive but more authoritative to move the students towards the scientific or mathematical story, and ending with a non-interactive, authoritative summation of the key ideas to take away. A non-interactive, dialogical summary of competing ideas may be injected at some intermediate point. As the communicative approach changes, so to will the *pattern of discourse* (aspect 4) that plays out in class. The teacher will orchestrate discussion to move students' understandings in the desired direction by way of various *teacher interventions* (aspect 5), some more appropriate to early stages of the lesson and some to later.

Within this evolution over the lifetime of a lesson or unit, with different characteristics being appropriate at different times, Mortimer and Scott perceive a frequent repeating of the general pedagogical pattern "explore, work on, review." They term this the "rhythm" of classroom discourse. *Explore*, they assert, is best served by an interactive, dialogical communicative approach; *work on* by an interactive, increasingly authoritative approach; and *review* by a non-interactive, authoritative one. No one approach is intrinsically superior.

Within the context of WCD in TEFA, we can be more discriminating. By definition, the whole class discussion phase of the question cycle is meant to be highly interactive; the "wrap-up" or "closure" phase following it is the place for a non-interactive summary, micro-lecture, or other strongly teacher-driven input. The WCD should generally vary from strongly dialogical (for questions intended to elicit and explore student thinking) to midway between dialogical and authoritative (for questions intended to make a specific pedagogical point). Within the span of a single question cycle's WCD, we may profitably evolve from a highly dialogical exploration of the answer spectrum to a strongly authoritative driving home of the key ideas.

Six Dimensions of WCD Quality

Sometimes WCD just doesn't seem to be working the way we'd like it to, despite our intentions and efforts. Identifying what exactly is deficient about it can be difficult, but without doing that, finding effective remedies — effective design changes or corrective teacher interventions — is tough.

As an aid in diagnosing discussion, we present the following scheme for evaluating the overall quality of whole-class discussion. It is meant to be diagnostic, not prescriptive. That is, it can help us identify what could be improved, but doesn't tell us what to do about it. Once a teacher has identified an aspect he or she wishes to improve upon, experience and inventiveness must generate tactics for making the improvement.

The scheme consists of ten different qualities that, taken together, describe ideal WCD. They are grouped into five related pairs. The qualities are listed below.

Participation

- Breadth: Do many or most students participate?
- Depth: Does participation take the form of nontrivial, thoughtful utterances?

Coherence

- Temporal: Does the discussion evolve in a coherent, logically related way, or does it jump around and consist of mostly unrelated fragments?
- Spatial: Are most of the students on the same page, or are different components of the class having different discussions in parallel?

Appreciation

- Value: Does the teacher validate students' contributions?
- Comprehension: Does the teacher really understand what students are trying to say, however poorly they may be expressing it?

Reaction (Contingent Action)

- Agility: Does the teacher adjust swiftly to information revealed by students?
- Soundness: Are the teacher's agile adjustments pedagogically sound and productive?

Closure

- Satisfaction: Do students feel that the discussion was of value to them?
- Pedagogy: Did the discussion successfully serve a teaching goal?

5. A Strategy for Managing WCD

Orchestrating WCD to draw out meaningful and varied contributions from a broad sample of students, engage students in a creative and critical exploration of the ideas, and move their understanding towards a more mature scientific or mathematical perspective is probably the most cognitively demanding task facing a TEFA practitioner.

One challenge is balancing dialogicity with authority: on the one hand, eliciting, respecting, exploring, and developing students' own points of view; on the other, developing the official, expert scientific or mathematical perspective one is supposed to teach. Another challenge is adjusting quickly and wisely when the discussion turns in an unanticipated direction. A third is simply processing and tracking all of the verbal action in order to weave it into a productive whole.

In order to help a teacher reduce this cognitive load and manage WCD more effectively, Mary K. Stein et al. have developed a strategy for "orchestrating productive mathematical discussions" {Stein-2004opm}. Although they apply this strategy to mathematics instruction, we find it to be equally useful for science instruction. In fact, it meshes quite well with the TEFA methodology. The remainder of this section summarizes a portion of paper, with some added interpretation about how it applies to TEFA.

Stein et al. take the perspective that

> The role of the teacher is to develop and then build on the personal and collective sensemaking of students rather than to simply demonstrate procedures for solving predictable tasks. {Stein-2004opm:3}

They identify a set of five practices that "make student-centered instruction more tractable by moderating the degree of improvisation required by the teacher during a discussion" {Stein-2004opm:7}. They do this largely by emphasizing the importance of planning, and by creating opportunities to substitute planning for reaction. The five practices are:

1. anticipating likely student responses;
2. monitoring students' responses during the explore phase;
3. selecting particular students to present their responses during WCD;
4. purposefully sequencing the student responses that will be presented; and
5. helping the class make connections between the presented responses.

The teaching context in which they situate the strategy is a three phase lesson. Phase one consists of "launching" a problem for students to wrestle with. The situation, available tools, and expected products are specified. During the second phase, students explore the problem and develop their own ideas and solutions, often in pairs or small groups. This is followed by a discussion and summary phase, in which students present and explain their approaches and solutions, the alternatives are discussed, and conclusions or key points are distilled and summarized. This maps directly to the TEFA question cycle. The launch phase corresponds to presentation of a CRS question; the explore phase to students' thinking and small-group discussions about the question; and the discussion-and-summary phase to the histogram, soliciting of reasons, whole class discussion, and closure/wrap-up portions of the question cycle.

Practice 1: Anticipate likely student responses

Prior to posing the question or task, one should "actively envision" a range of ways in which students are likely to approach the question. This goes beyond assessing whether the question's difficulty level is appropriate and whether students are likely to get the "right" answer. It involves considering alternative interpretations of the question and alternative aspects that students might focus upon, and brainstorming various strategies and beliefs, right or wrong, that students of various levels of sophistication might try to apply. It also involves contemplating how those strategies connect to the scientific or mathematical points to be made with the question and the pedagogical opportunities that may arise.

This is easier in TEFA than in the more general problem-solving context discussed by Stein et al., since the "tasks" given to students as CRS questions are generally small in scope, limited in duration, and often require selection of a multiple choice response. This makes the space of possibilities to anticipate manageably contained.

We advocate that when creating multiple choice questions, a teacher choose distracters (wrong or sub-optimal choices) that correspond to specific misinterpretations, misunderstandings, and mistakes he or she believes students are likely to form, have, or commit. If this admonition is followed conscientiously and thoroughly, most of the work of the first practice is already done.

If possible, brainstorming with a colleague is a powerful way to think of alternative student approaches. Recording ones discovered in class for use in future classes is also beneficial.

Practice 2: Monitor student work during the exploration phase

The second practice involves attending carefully to what students are saying and doing as they work through a question during the "explore phase." The teacher's goal with this practice is to survey the specific strategies or concepts or techniques that different students are bringing to bear, and to note those that would be valuable to elicit during WCD. With sufficient reconnaissance, the teacher need not be surprised by the CRS histogram when it appears.

Practically, this kind of monitoring is rarely possible for individual tasks unless they contain an external, visual component such as drawing. When students talk in small groups, however, one can circulate and eavesdrop. If one interacts with individuals or groups, perhaps offering clarifications or hints, so much the better.

If practice 1 has been faithfully implemented, many of the approaches one observes should be expected. This makes keeping mental track of the data easier. If something unanticipated is seen, one might ask the students to briefly explain what they are doing, not to help or correct but to be better prepared for WCD.

Practice 3: Select particular students to present responses

By selecting which students speak during WCD, knowing something about what these students are likely to say from the monitoring of practice 2, a teacher can influence the set of ideas that are raised in the discussion. This is most commonly done to make sure that important points are elicited and can be developed, but can occasionally be used to avoid dealing with a particular approach that the teacher is not yet ready to handle.

This practice can be somewhat awkward to incorporate into TEFA, since it conflicts with the common practice of asking for volunteers to argue in favor of various answer choices. Furthermore, it can easily squelch unsolicited student contributions and prevent highly desirable TSS and SSS interaction patterns from arising. However, the teacher may find specific questions or topics for which paying this price is worthwhile.

A practical compromise is to begin the WCD by asking for volunteers to defend any (or one specific) answer choice. If the teacher has the luxury of many raised hands, he or she chooses from among them based on foreknowledge of (or an informed guess about) what they will say. If nobody volunteers, the teacher changes modes and calls on students based on such knowledge. If there are only a few volunteers, the teacher lets them say their piece, but then instead of exhorting others to step up, he or she begins calling on individuals. Room for spontaneous volunteering is preserved, but for many questions the teacher can still arrange for the desired positions to be voiced. This has the added advantage of communicating to students that they are responsible for justifying their answers whether they volunteer to do so or not. It has the disadvantage of forfeiting the psychological benefits of anonymous response, unless the teacher chooses students carefully with knowledge of their psychology and confidence.

Another hybrid implementation of this practice that meshes well with TEFA — especially for classes in which students rarely offer thorough arguments on their own — is to first let students volunteer to “explain” their reasons for choosing specific answers, and then to select specific students who have spoken and work with them (think IRFRF…) to extract a deeper, more comprehensive position. Rather than press each volunteer for elaboration as he or she speaks, we first solicit initial offerings from all volunteers, and then choose which of them to revisit in more detail.

Practice 4: Sequence student responses to build a progression

This practice is a straightforward extension of the previous one. If we choose which students speak, we can also choose the order in which they speak. This provides us with some ability to create a logical "flow" of ideas and move the class' understanding in the desired direction. For example, we might want elicit and dispel a common misconception early, so that it does not interfere with students' thinking about the question from other, more productive perspectives. Or we might wish to have the most robust line of reasoning exhibited and digested first, so that others can be understood as minor deviations from it. Or we might choose to sequence responses into groups that share common assumptions or approaches. (Regularly eliciting flawed arguments first and saving the "right" one for last is pedagogically tempting, but students quickly learn to interpret the pattern and avoid speaking early.)

Another, gentler way to exert some influence over the order in which ideas are injected into the discussion is to ask for volunteers to offer arguments in favor of each answer choice or histogram bin, but to choose the choices or bins with malice of forethought. Knowing what lines of thinking are likely to lie behind each choice, we can at least attempt to have arguments or ideas raised in the order we prefer. The more strongly specific answer choices are correlated with unique solutions, the better our control. And what we learn from monitoring student work, according to practice 2, can improve our ability to predict what ideas will come up for which answer choices.

Free-flowing, spontaneous, unsequenced student discussion has its own benefits, so practice 4 should be exercised with care and moderation.

Practice 5: Make connections between responses

The objective of this practice is "to have student presentations build on each other to develop powerful mathematical [or scientific] ideas" {Stein-2004opm:13}, by drawing students' attention to the ideas underlying their solutions, and highlighting connections, parallels, key differences, dependencies, and the like. We can accomplish this by interjecting our own observations about the relationships between things students have said, or by challenging students to identify similarities and differences. Such connection-making can begin during WCD with an interactive, semi-dialogical approach, and continue in the question cycle's closure phase with a non-interactive, perhaps more authoritative approach.

The benefit

Overall, the "five practices" strategy of Stein et al. do not diminish the amount of thinking we must devote to the challenge of turning dialogical student discussion about questions answered into directed learning that satisfies our instructional goals. They do, however, distribute that thinking more widely, so that much of it occurs during class preparation (question design) and the "exploration" (question-answering) phase, making management of the actual WCD interval more tractable. As a side benefit, it also positions us to learn more from the experience about our students, our TEFA questions, and the pedagogical content knowledge of our subject.

6. Tips for Successful WCD in TEFA

In this section, we present a loose collection of "tips" for getting the most out of TEFA's WCD phase. This collection is a mixed bag of general (and perhaps vague) principles, specific tactics, unabashed opinions, and concrete ideas. It is neither a comprehensive framework, a prescription, nor a list of rules. The tips are crudely organized into sets addressing similar aspects of the teacher's role in WCD.

These tips are intended as suggestions, not gospel truth. Some are valuable in moderation and toxic in excess.

They are meant to help you achieve successful TEFA WCD, but "success" varies according to the subject, level, class personality, and other contextual factors. It is the teacher's duty and prerogative to define success within his or her own context. Not all of the tips are equally viable in all contexts. *Caveat emptor.*

Framing tips

Students' social expectations and their framing of a task have a strong, sometimes insurmountable, impact on their behavior in WCD. Accordingly, it behooves us to monitor these and to expend some effort altering them in beneficial ways.

1. Teach students how to participate in WCD

According to Mortimer and Scott {Mortimer-2003mms:23},

> [For students,] learning the speech genre of school science [or mathematics] includes coming to recognize when it is appropriate to offer their point of view and when they are required simply to "guess what the teacher is thinking."

More generally, students don't necessarily know that they're supposed to coax their nebulous and limited understanding into words, or reason based on everyday views, or try speaking an unfamiliar and awkward social language just because we want them to. We have to teach them that these things are desirable at times, and how to decipher what those times are. And we have to be persistent, insistent, consistent, and patient, because we may be pushing against several years of contrary conditioning.

Sometimes, when a student says something "wrong," we'd be better off correcting their *framing* of the situation than correcting their content knowledge.

2. Cue students to the content type under discussion

We can partially implement the previous tip and improve students' contribution to WCD by signaling to them what the *content type* (aspect 2 of the framework presented in Section 4) currently being addressed is. What aspect of the question, its introduction, or its context should inform students whether everyday or scientific/mathematical language and ideas are expected? What hints whether description, explanation, or generalization is sought? Is empirical or theoretical justification demanded? "Low-quality" contributions to discussion are often just contributions of a different type.

3. Metacommunicate habitually

Cueing is subtle and often operates implicitly; metacommunication is blunt and explicit. In addition to cueing students about how they should participate, tell them. Tell them frequently, in various words. Itemize the variety of ways they can participate, and sensitize them to the necessity of making a choice. Here are some examples.

To stress that explaining one's thinking, not being right, is the goal: "I don't care about *what* you think anywhere near as much as I care about *why* you think it."

To signal a change of content type and sensitize students to the existence of different content types: "The last question wanted you to predict what would happen in a situation, and most of you did that based on your real-world experiences. That was appropriate. This question is different: it wants you to use the language and concepts we've been learning in class to explain why that *ought* to be what happens."

To solicit additional points of view for dialogical discussion and change students' goal for participating: "Can anyone think of a different way to interpret the question? This is about being creative, not about being right."

Sequencing Tips

In addition to social expectations and framing, the temporal context of a discussion — what has come before — shapes how students participate and how the discussion unfolds.

4. Don't skip steps in the sequence of teaching purposes

The six "teaching purposes" of aspect 1 of the Mortimer and Scott framework (Section 4) all exist and are ordered that way for a good reason. Attacking later ones without addressing earlier ones is asking for trouble.

5. Feel the rhythm

Mortimer and Scott argue that different phases of instruction are best served by different communicative approaches, and that student-centered teaching falls into a natural "explore, work on, review" cycle supported by a rhythm of "dialogical and interactive, increasingly authoritative but still interactive, authoritative and non-interactive" intervals. Look for this rhythm, experiment with it, get comfortable with it, and build on it.

6. Mix challenges, traps, and confirmation

If no task is at or beyond the limit of students' reach, they never stretch; if all are, they get frustrated and give up. If no question lays a trap for them, they never learn to be defensive and challenge their first reactions; if all do, they learn not to take questions seriously. If no question asks for thinking they have mastered, they never feel confirmation and recognize progress; if all do, they never perceive a necessity to challenge themselves. Mix it up.

7. Don't smooth the path

Removing the bumps, potholes, wrong turns, and blind alleys from the path students must travel deprives them of the opportunity to learn avoidance and navigation skills. Don't warn them about likely misinterpretations of or tempting mistakes on a question; let them trip over something, help them recognize what happened, help them figure out how they could have avoided it, and let them try again. The best-designed question in the world can be emasculated by pointing out in advance all the errors to avoid.

8. Use small group discussion to prepare Ss for better WCD participation

In our experience with TEFA, having students engage in small-group discussion before submitting a CRS answer sets up higher-quality participation in the following WCD. For one thing, students can make statements as "we think" rather than "I think," which emboldens them. For another, students are less afraid of being wrong than of being incomprehensible and inarticulate; small group talk lets them rehearse things to say. For a third, articulation clarifies thought, and students are disinclined to share what they grasp only fuzzily. Should we really wish to assess with our CRS how individuals answer on their own, we are inclined to collect answers twice: once before small-group discussion and once afterward. This supports both formative assessment *and* good WCD.

Question design tips

Some types of TEFA question promote rich, productive WCD. Some all but destroy the possibility. Learning to create questions that set up good WCD — for *your* particular group of students — is a cornerstone of successful TEFA practice. But keep in mind that stimulating WCD is not the only use for CRS questions. Sometimes we just want to know how many students can solve a particular problem, or we want students to know whether they can.

9. Avoid "you know it or you don't" questions

The most fundamental rule of WCD-oriented question design is to avoid questions which students either do or don't know how to answer. Those who "get it" simply assert the right response; those who don't get it know they don't, and either guess or abstain, neither of which provides much to contribute to a discussion.

This is quite possibly the most oft-violated rule of WCD-oriented question design, too.

10. Use qualitative questions

If the process of answering a question is difficult to talk about in words, discussion is inhibited. The solutions to qualitative questions are most amenable to verbal description. Qualitative reasoning is usually thought through in words, and so is easily expressible. Articulating quantitative reasoning generally leads to speaking many variables and numbers, which leads to glazed-over eyes.

11. Avoid quantitative or calculation questions

This tip is directly implied by the previous tip. It is, however, important enough to reassert.

12. Focus on relationships between quantities, not values

A corollary of tip #10, questions about how quantities relate (as opposed to what their values are) provide more room for qualitative reasoning and easier verbalization. "If X is increased, how will Y change?"

13. Provide inscriptions as a focus and concrete object of reference

Having an "inscription" — a concrete, often visual representation of data, relationships, characteristics, or other aspects of things — provides students with something tangible to reason about and refer to, something to point to for clarity and support. This enhances discussion. Useful inscriptions include diagrams of various generic and subject-specific sorts, data tables, graphs, lists, maps, text excerpts, and mathematical propositions {Forman-2002omv}. Inscriptions can be included in question statements, suggestively available in the students' context or environment, proposed by the teacher, or invented by the students themselves.

14. Situate questions in contexts meaningful to students

Abstract, disembodied questions can be difficult for many students to appreciate, answer, and talk about. Situating a question in a comprehensible context, especially a "real world" context meaningful to them, helps such students sink their teeth into it and find something to offer in discussion. It also helps them reconcile a strange new scientific or mathematical social language with familiar everyday social languages.

15. Ensure questions are disputable

To enable meaningful discussion, a question must be disputable. That is, it must possess at least one aspect about which reasonable students can disagree. Reaching different answers because one of us guessed does not count as disagreement; neither does holding different opinions about a purely subjective matter. ("Red Sox!" "Yankees!" "No, Red Sox!" "No, Yankees!!")

16. Create a conflict or dilemma

One general technique for making questions disputable is to impale students on the horns of a dilemma or otherwise throw them into internal conflict. Most likely, some will come down on one side and some on the other when forced by the CRS to make a call, and may will waver when encountering opposing perspectives during WCD.

17. Require nontrivial defense or justification

This is implied by several of the previous tips, but bears articulating separately. If the justification for a particular response is trivial, there's not much to discuss; one asserts it, and others either agree or disagree. For worthwhile WCD, positions should require justification of sufficient complexity or subtlety. ("Sufficient" depends strongly upon the capacities of the students involved, but those capacities should be exercised to their limits as often as possible.)

18. Have multiple defensible answers

A concrete technique for implementing tip #15 and perhaps #16 is to build a question for which more than one answer is reasonably defensible. Perhaps how one interprets some aspect of the question situation, or whether one makes a particular assumption, or how one prioritizes competing factors determines which answer one selects. Through WCD, disagreement over the answer can be traced back to its root cause, and the virtues of alternative choices weighed.

19. Be deliberately ambiguous

As suggested in the prior tip, allowing ambiguity to remain in a question can lead to multiple defensible answers. It can also lead to fruitful discussion about whether the question is ambiguous, what the exact ambiguity is, the impact of alternative resolutions to the ambiguity, the inherently ambiguous nature of all communication and life, the necessity of being watchful for ambiguities, and strategies for resolving them. It can also make students feel unfairly tricked if overused or insufficiently metacommunicated about.

20. Require assumptions

This is a slightly different spin on the previous tip. It can engender discussion about the omnipresence of assumptions in mathematical and scientific thinking, the specific assumptions mathematicians and scientists consider routine or acceptable, and criteria for deciding what assumptions are reasonable in a given situation.

21. Require choosing from among competing approaches

When more than one idea, strategy, perspective, procedure, or tool can plausibly be used to address a question, students must make a choice about how to proceed. WCD can then focus on the relative merits of alternative candidate approaches: which are defensible, which are most effective, which are most efficient, etc. It can also highlight the fact that in both science and mathematics, choosing *what* to attempt is at least half the battle.

22. Require multiple ideas or steps

If answering a question demands that students string together multiple ideas, stages, arguments, or other steps, richer discourse is possible as students explain the steps, how they fit together, and whether a simpler solution might exist.

23. Require mixing new knowledge with old

By posing questions that require a mixture of new and previously-learned knowledge to answer, we expand the space of the discussion beyond the “current” topic. Discussion can thus draw in facets of the current topic, facets of any relevant earlier topics, and the higher-level relationships between them. Such questions also help prevent “pigeonhole learning” and foster the construction of more integrated knowledge. This style of question can naturally combine with that of tip #21 if the alternative approaches of that tip come from chronologically separate units or topics.

24. Invent diagnostic distracters

This tip differs from the previous ones. Rather than directly impacting the possibilities for discussion, it helps us better manage discussion by implementing practices 3 and 4 of the Stein et al. strategy for orchestrating WCD (Section 5, above). If a student's choice of answer reveals with high probability the specific approach, idea, or perspective they used, we can more effectively decide who to have speak, and when.

Listening Tips

Listening is a crucial component of discourse, and how a teacher listens to what students says impacts what students say and how the teacher can respond.

25. Give them time to think, and more to tell you what they think

Thinking takes time, especially when thinking with new tools. Formulating utterances also takes time, especially when coming to terms with a new social language. Give students more time than it seems they should need to figure out what they think and how to say it. Become aware of your own "wait time," the duration you'll wait in silence for someone to respond to something. And when a student struggles to articulate something, spend the time to help him or her patiently, for great learning comes from such struggle.

26. Listen interpretively, not evaluatively

When a student makes an assertion or responds to something you ask, are you focused on what's right or wrong (good or bad, desirable or undesirable) about the student's utterance? Or are you focused on figuring out what the student *means*, what he or she is trying and perhaps failing to say, and — most importantly — *why* he or she would think to say that? The first leads to authoritative IRE-based discourse and a "guess what the teacher wants us to say" mentality; the second to more genuinely dialogical discourse, less frustrated students, better understanding of your students, and more effective instructional interventions.

27. Downplay "correct" in favor of "cogent" and "defensible"

Stressing the correctness of students' statements makes them want to be correct, which makes them disinclined to speak unless they're confident about their thinking, which means the ones who most need to get it articulated and examined are least likely to. Stressing the cogency and defensibility of students' statements makes them want to be cogent, which encourages them to focus on their reasoning and challenge what seems true, which is exactly what we would like them to do more of.

28. Imagine a situation in which an incorrect statement would be correct

In our experience, a student who appears to be offering an incorrect answer is quite frequently offering a reasonable answer to a different or incorrect question. He or she may have framed the question differently, misinterpreted the situation, assumed something different, or simply lost track of exactly what should be reported at the end of the mental machinations. If we simply say "wrong," we confuse him or her further, because we've communicated that something is flawed in his or her possibly quite correct reasoning. A better reply is for us to say "that would be correct if…" and indicate some related situation or question for which the answer would have been appropriate. The student benefits even if he or she was flat-out wrong, and so do all the other students, because they can now contrast two related situations and see how a small difference impacts the answer. Motivationally, it's also less disconfirming.

29. Consider "errors" as poor language, not misunderstanding

Remember that learning science or mathematics is akin to learning a new language, and think of errors that students make as poor language use rather than as failures or inadequacies. We expect use of a newly encountered language to be poor and stumbling at first, and we patiently tolerate that because we recognize it as the only path to fluency. We are also inclined to react to poor language use by making an effort to see the meaning behind the clumsy speech, by reinforcing the successful bits, and by modeling fluency for the learner. In science and mathematics also, these attitudes are more conducive to learning than evaluation and reducing expectations to what the learner can "succeed" at.

30. Stay watchful for potential clashes between everyday and formal language

Apparent "errors" in what students say may be the result of conflict between an everyday social language familiar to the student and the science or mathematical social language we are teaching. They may also result from using one when the other is expected. Remaining attentive to this possibility can improve our diagnostic acumen and improve communication.

Discussion management tips

Actions by the teacher during WCD can steer how discussion unfolds, for good or ill. The right intervention at the right time can open up a new level of discourse, draw out a previously reticent student, or cause light bulbs to turn on in many heads. Counterproductive discussion-handling habits can stall discourse in its tracks.

31. Try to talk less than the students do

This tip may seem self-evident, but it can be very hard to do when the adrenaline is pumping, the mind racing, twenty-some pairs of eyes are watching, and twenty-some mouths are stubbornly refusing to say very much. Most students will quite happily let a teacher fill all available talking time if the teacher is so inclined. And teacher-talk sends an implied message that "this is more about what's going through my head than what's developing in yours."

32. Avoid the "figure out what the teacher is looking for" dynamic

Guessing what the teacher wants to hear is a survival strategy in school, and most students have developed it to a fine art. Unfortunately, it has little to do with learning, and it is poison to real discourse. If you find yourself engaged in IRE triads or fill-the-blanks "discussion," reconsider.

33. Focus on "why" and "under what conditions," not "what" or "whether"

Fundamentally, "what" and "whether" are about fact: what is or isn't true. While important, that doesn't provide much fodder for discussion to chew on beyond assertions of agreement or disagreement. "Why" and "under what conditions," however, lead directly to analysis of causal relationships and reasoning, which is far more fertile turf.

34. Practice and encourage uptake

Uptake means use of one person's utterance by another person in subsequent discourse. If a student offers an idea and the teacher then explores it, or refers back to it later, that's "teacher uptake." If, instead, another student relates or contrast his or her own position to it later, that's "student uptake." Studies have indicated that uptake correlates strongly with outbreaks of rich dialogical discourse in classroom discussions {Nystrand-2003qti}. Uptake validates participants' contributions, develops dialogicity, and supports collective meaning-making. So whenever possible, find ways to build on or refer to students' utterances, and encourage students to do so as well. Simple questions like "How does Beverly's idea differ from Garrett's?" can do wonders.

35. Capture students' ideas on a whiteboard

One concrete technique for practicing and encouraging uptake, promoting cohesion within discussion, and providing inscriptions for students to refer to (cf. tip #13) is to summarize key student contributions on a whiteboard for all to see. Incidentally, this also helps the teacher keep track of ideas raised in order to better steer and, ultimately, summarize the discussion.[1]

36. Paraphrase with care and purpose

Paraphrasing a student's utterance back to the class is a double-edged sword. On the one side, it can promote uptake and dialogicity by making sure the utterance is heard and noticed, and it can further the teacher's aim of moving student thinking towards scientific or mathematical expertise

1 Thanks to Chevy Seney of Frontier Regional School for this idea.

by marking key ideas and perhaps shaping them through partial omission or alteration (cf. aspect 5 of Mortimer and Scott's framework, Section 4). On the other, it can stifle TSS and SSS interaction patterns and reduce interactivity by channeling all student interaction through the teacher. Wittingly or unwittingly, subtleties about when and how paraphrasing is done can act as evaluation of student utterances, leading to IRE style interactions. Paraphrasing should be done delicately, rarely, and from a stance of interpretive listening and respect for dialogicity.

37. Ask students to clarify each other

A clever trick to promote student uptake, encourage students to confront and explore each others' points of view, invite TSS interactions, and gain additional insight into student thinking is to ask a student to explain, clarify, or elaborate upon another student's statement or position. It is not necessary that the second student accurately or correctly understand and represent the first's position; in fact, it is more interesting if he or she does not, because that generally leads to an argument about what the first student really meant, to the benefit of all.

38. Instigate argument

In WCD, disagreement is good. It indicates multiple points of view to be explored and reconciled, which leads to learning. It enables meaningful discussion. If the students don't disagree as much as much as one might like, provoke argument. Bait, challenge, play devil's advocate, and switch sides. Make it a game to disagree.

39. Don't celebrate unanimous histograms

We don't cheer when the CRS histogram shows a single dominant peak for two reasons. The first is that it means we have little disagreement, ergo little opportunity for dialogicity, to work with. Either the vast majority of students gets it, in which case all we can do is move on, or the vast majority committed the same blunder, in which case we have some serious clean-up to do. (The best outcome is that they all interpreted the question differently than we intended, so that we can at least have some meaningful metacommunication about that.) The second reason is that it reinforces students' deeply held belief that getting it right, rather than being creative and cogent and letting it all hang out and contrasting ideas, is the proper goal.

40. Practice deadpan and devil's advocate

As we just mentioned, students are deeply, deeply attached to the idea that their objective in just about every school context is to provide the "correct" answer, whether or not they understand why it's correct. And to them, correct means "what the teacher wants to hear." They're watching us closely for clues as to what's right or wrong, so if we want to develop serious dialogical discourse based on the volunteering of multiple points of view, we'd better have an impenetrable poker face. Playing devil's advocate, and having students know that we do so frequently and without warning, helps communicate that we're really more interested in the argument than the answer.

41. Ask for speculation about silent students' thinking

If we show a CRS histogram and nobody can be cajoled into speaking up in defense of their own choice, a simple trick to jump-start discussion is to ask students to hypothesize reasonable arguments on behalf of a position they do not personally subscribe to. This can often spur someone to speak up in their own defense, because most people hate being misrepresented. However, this trick should be used stingily as a last resort, or students will use it as an excuse not to commit to any position. Dialogue is more productive and learning is greater if students are personally invested in their choices and defense of it. Unwillingness to claim a position as one's own is a sign that a student is still fixated on being right, rather than on learning.

42. Inject tools to help students think, not answers

At times, an instructor will inject bits of content knowledge into a discussion to help students make progress. Dropping in answers, parts of answers, or pointers towards the answers is not generally so beneficial, because although might help move students to a state of knowing the answer, it does not particularly help them develop the capacity to reach such an answer themselves. Rather, we should help them by injecting new thinking tools or reminders about thinking tools they have previously encountered, with which they can find their way to the answer. (Better yet that we provide hints that help them select the right tools by themselves, since that too is an important skill.)

43. Move them to the goal incrementally

Similarly, resist the temptation of trying to lead or push or coach them to some desired state of understanding all at once. Knowledge is not gained all at once, but built up incrementally and through multiple passes. Rather, aim to find out where they are, and then move them incrementally, a bit at a time.

Self-Monitoring Tips

The more self-aware and self-monitoring a teacher is, the more effectively he or she can prepare for and participate in discourse.

44. Articulate your teaching purpose and content type focus

Identify to yourself the teaching purpose (Mortimer and Scott framework aspect 1) and content type (aspect 2) of each question cycle you plan. The more clear you are on your goals, the more wisely you can choose your approach.

45. Keep an eye on your communicative approach and interaction patterns

Develop a habitual self-awareness of the communicative approach (Mortimer and Scott framework aspect 3) you are using at any point in time, and of the interaction patterns (aspect 4) going on in your classroom. Make sure these align well with your teaching purpose and with your current place in the "explore, work on, summarize" rhythm.

46. Practice meta-narrative

More generally, build the habit of narrating to yourself what you are doing, and why, as you go through sequences of teaching actions.

47. When WCD is disappointing, reflect on the six dimensions of quality

The "six dimensions of WCD quality" scheme is a tool for comparing real discussion to a best-imaginable model. When you're unhappy with the WCD you're getting, or just want to make it better, consult the scheme.

48. Worry more about what students think than what they should think

Paradoxically, the most effective way to get them to understand what they ought is to forget about what they don't know, and instead focus on what they presently think. Understanding and interacting with that is what helps them evolve their thinking and integrate new thought patterns, rather than trying to remember a set of answers and rules that doesn't really make sense to them and doesn't mesh with everyday thought.

49. Remember that learning takes more time than you think it should

It is often a slow process. Even when sudden leaps of understanding occur, it takes time for all the implications to be realized and sorted out.

50. Stretch your comfort zone

To get better, take risks. Mix it up. Experiment. You'll gain more than you lose.

51. Dare to surrender control (then take it back)

You can't learn for the students; they have to do it themselves. So, give up control of the teaching/learning process for a while. Then reclaim it and use your superior perspective to impose direction, after the students have churned up new material to work with.

52. Create opportunities to talk about teaching

Extend your teaching expertise the same way you want your students to extend their science or mathematics expertise. Seek out the dialogical interplay of alternative ideas and perspectives with colleagues, spouses, or anyone else who will engage — even your students.

53. Have fun

If you do, your students will too.

References

Not added yet (this is a draft, after all). Contact the author if you want to know what a particular citation refers to.