ASSESSMENT AND THE USE OF CLASSTIME

PURPOSES OF ASSESSMENT

Assessment serves many purposes. It provides information about the current state of our students' understandings and abilities and helps us determine what they and we need to do next in order to make progress. Assessment informs students and teachers about the degree to which students are meeting the objectives of a challenge, the ways in which they accomplish their work and think about the ideas, and the strengths on which they can build. Assessment should be a daily concern for teachers and students alike.

Assessment is most effective when we are clear about our goals for a unit. Do we want the class to have a taste of the research process, for each group of students to produce a clear conjecture, or for each student to produce a major report? Once we are clear about the end results that we seek, we have a better sense of the skills and stages that we will need to assess.

MEANS OF ASSESSMENT

The most natural way to assess students' research abilities is through ongoing observations and discussions during research experiences. Students may reveal their understandings and questions through a written log, small-group discussions, an oral presentation, a one-on-one meeting, or a formal report. You want to be able to document what each student and group is doing: the progress that they are making, the habits and skills that they are exhibiting, and the difficulties that they are encountering. This data will allow you to provide positive, constructive responses that help the students reach their goals. Ongoing assessment, as opposed to after-the-fact comments on final reports, encourages steady progress and, therefore, efficient use of time.

When studying a student's written efforts, look to see how detailed her work is, seek evidence of multiple approaches to a problem, and identify which methods and lines of reasoning she tends to employ. You want to develop a picture of her habits of thought so that you can further encourage their use as well as guide her in new, complementary directions. Keep your own log for each student of noteworthy observations, questions, techniques, and behaviors. Every time kids are working independently or in small groups on class problems, wander around the class, taking notes on what habits and skills kids are exhibiting. You can record these notes as you observe groups working in class or after a class when highlights will stand out in your mind. Do

not just keep your observations to yourself. The more you point out positive actions and the effect they have on progress with a question, the more students will be alert to repeating them.

At times, you will want to quietly observe students as they work, but you should also check in with them regularly and ask questions that will give you an overview of what they are doing. The questions that you ask will both model for your students what they need to be asking themselves as well as provide insight into a student's thinking. Good general questions include:

- Where are you in the research process?
- Why did you take that step, use that representation, or try that case?
- What questions do you have?
- What are the different directions that you might head from this point in your research?
- What expectations do you have for your result? Can you place limits on what it might be? Is there a form that you expect it to have?
- Why do you think that that claim is true?
- How can you check your result?
- What will you be doing next?

Be sure to ask these questions of all students regardless of whether you think they are on the right track or not. Persistence on your part will yield two benefits: (1) your students will understand that they should ask themselves these same questions and (2) sometimes you will find that seemingly correct results have come from rather shaky thinking and that answers that seem off-base have, lurking in the background, some sound reasoning. When a student always looks for a way to check her work, then, when she is right, she will discover multiple ways of explaining her idea (and thus make new connections, which she would not have made if you just told her she was right). When she has made a mistake, she will learn to be more skeptical and will be more likely to notice conflicting information.

See How do I help my students during research? in Introduction to Research in the Classroom for a list of questions for each stage of the research process. For more specific questions that assess different aspects of the research process, see the discussions of how we evaluate what makes a good conjecture, proof, or definition. For other valuable advice on questioning students see:

- Steven Reinhart (2000). *Never say anything a kid can say!* Mathematics Teaching in the Middle School, 5 (8), 478–483.
- Mark Driscoll (1999). *Fostering algebraic thinking*. Portsmouth, N.H.: Heinemann.

Our goal should be for students to improve in their ability to assess their own work (after all, most of us, as adults, receive relatively sporadic feedback and need to be the main engines in our own learning and reviewers of the quality of our efforts). If students write answers to the different questions listed above and reflect on what they have done well and what they need to give greater attention to, they will grow into confident, flexible, able researchers.

FEEDBACK AND EVALUATION

A major area for assessment is the clarity and effectiveness of a student's ideas and writing. Teachers are quite talented at reading between the lines of a report and figuring out what a student seems to have meant. While this is good to do in order to gain a full understanding of the student's thinking, it is also helpful for students to get responses from less charitable readers. Students make a great audience for one another because they do not have the background that enables them to make sense of incomplete explanations. If you provide time for classmates to regularly read and ask questions about one another's conjectures and proofs, the students will get a clear sense of what it takes to communicate an idea clearly and convincingly. Peer review also helps to build a mathematical community in the class and supplements the teacher's efforts to give regular feedback. (See Writing Conjectures in the Conjectures section for further discussion).

Research can be assessed, and evaluations can be provided, in numerous areas including:

- Understanding of the research question
- Understanding of the research process
- Persistence
- Creativity in problem-posing
- Creativity in problem-solving (e.g., multiple means of solution, innovative methods, making of connections, effective representations, etc.)
- Organization and attention to details
- Correctness of technical work and of proofs

- Sophistication of results (How general are they? How subtle are they?)
- Quality of writing

There are so many understandings and skills on which students need to work that each student is guaranteed to have areas in which they do well and areas that they need to refine. One way to minimize the stress associated with long, open-ended problems is to note regularly the evidence you see of habits that students engage in successfully. Help them to see their areas of strength (e.g., "You have been quite effective finding visual representations of problems.") and to be patient with the tasks that they find challenging. Point out that as a group they make progress because of their individual contributions. When students realize how multi-faceted their work is, then they are less frustrated when they are only partially successful with a given research problem.

Grading

Research can be highly motivating and the results that students derive can be their own reward (especially when coupled with the responses of an appreciative audience). Grades are often used as a way to motivate students to work, but in the case of research, with all of its uncertainties, the prospect of a grade can lessen students willingness to take intellectual risks (See Alfie Kohn's (1999) *Punished by rewards.* Houghton Mifflin Co.). If you do need to grade students' research efforts, here are some suggestions:

- Don't use grades early on in students' exposure to research. Wait until the process is more familiar and students have had some success generating conjectures and proofs.
- Don't average disparate skills together. Rather than trying to weight creativity versus rigor, provide distinct feedback on each research skill (e.g., problem posing, organized exploration, conjectures, reasoned arguments, clear notation, use of definitions, cycling through increasingly complex observations and proofs, persistence and initiative).
- Always note areas that students should focus on for improvement, so that the goal of improvement is present for all students (otherwise, students who are satisfied with their grades will tend to rest on their laurels).
- Reward students for what they do well rather than what they fail to do or can not yet do. If a student has a wonderful conjecture, that may be impressive enough to warrant a good grade. One of our students won recognition at the local, state, and international science

fairs for a series of questions, computations, and conjectures. His ideas were sufficiently original that his lack of a proof was not evidence of a lack of careful mathematical thinking.

- Allow students extra chances to complete a task successfully (make the effectiveness of their thinking and not the speed of their thinking the valued trait).
- For group projects, give a group grade. The alternative makes for wildly subjective judgements about the role that each student played and discourages group effort. The grade can be based on the group's effort, their success in following a reasonable research process, the quality of their final report, and how well each member of the group understands, and can answer questions about, the project.

USE OF CLASS TIME

When students are doing research, class time often consists of small group or individual work time. After these intervals, students may do presentations of their work to the whole class and field questions or the class may share results and make observations. One drawback to whole class discussions can be that only one student is talking at a time. That usually means that several other students are not actively thinking about the subject at hand. One way to increase involvement is to avoid calling on a single student to answer a question. Instead, when an interesting question arises, write it down and ask everyone to write a response. As they do so, you can look at their papers and determine how well each student understands the issue. This method gives everyone time to think about the question and formulate an answer rather than rewarding the fastest and most energetic hand-raiser. It assures that everyone participates while eliminating fear of embarrassment for wrong answers. For students who are shy or insecure, you can be sure to call on them whenever you see that they have an interesting comment written down.

When students are asked to think about a question, give them time to think about and then write thoughtful answers. Help them develop the habits of taking their time and of being patient with a problem. On the other hand, you want them to use that time efficiently, so give them a specific amount of time that will encourage them to attend immediately to the question. For example, studies show that if you give students an amount of work time that sounds precise (e.g., “You have six minutes to work on this.”), they will get to work more promptly than if you pick a

"round" number such as a multiple of five. When you are calling on students for verbal answers, allow a reasonable length of time before students can raise their hands (see Stahl, Robert. *Using "think-time" and "wait-time" skillfully in the classroom*. 1994-05-00. ERIC Clearinghouse for Social Studies/Social Science Education at http://www.ed.gov/databases/ERIC_Digests/ed370885.html, but note that while the research often studies periods of time as long as three seconds (!), many teachers find that periods of minutes, hours and days can prove to be the optimal interval for reflection about a question.)

If student responses are not in agreement, you can have the students work in pairs to analyze the contradictory claims, to look for the good reasoning in each, and to try to find the truth(s) of the matter. Try to encourage discussions between the students rather than ones that alternate between the teacher and the class. One way to do this is to have each speaker call on the next participant so that you do not have to be the central moderator all of the time. You can also ask questions but refuse to settle a question for the class. Real research questions do not have the "answers in the back of the book." If you refuse to play that role for them, then students learn that the only route to a right answer involves refining and rethinking their arguments and listening to their classmates' reasoning. In the face of disagreements, students seek to present justifications that are more persuasive or consider becoming less convinced by their own interpretation.

