

Assessment in the Inquiry Classroom **by Wynne Harlen**

Because assessment information is a powerful tool for monitoring the development of student understanding, modifying activities, and promoting student self-reflection, the effective teacher of science carefully selects and uses assessment tasks that are also good learning experiences. These assessment tasks focus on important content and performance goals and provide students with an opportunity to demonstrate their understanding and ability to conduct science.

—National Science Education Standards

Assessment—the process of evaluating the quality of learning—is an integral part of classroom teaching. With children taking different paths as they learn, assessment in the inquiry classroom can be a difficult task. But, as this essay points out, the characteristics of inquiry give teachers the opportunity to determine what students are learning, recognize when they need help, and identify appropriate next steps to take.

"Any assessment is only as good as the action that arises from it."

—M. James (1998)

Picture the scene...

A fourth-grade class is involved in a topic on sound, investigating how it is produced and how we hear it. The teacher has collected a number of musical instruments—tambourines, recorders, several homemade one-string guitars, a real guitar, drums, castanets, triangles, and so on—deliberately including some that can be tuned and others that can't.

These are distributed to the students, who are working in groups. The students are asked to find out several things, including how to make a loud sound, a soft sound, a high-pitched sound, and a low-pitched sound. They are also asked how to stop the instrument from making any sound at all, and how to stop themselves from hearing the instrument when it is making a sound. The students are to discuss their findings and prepare to present what they have done and their ideas about it.

As the students work, the teacher circulates, listening to their talk. She encourages their thinking by asking questions, such as, What do you do that makes the difference between a loud and a soft sound? or Why do you think doing that makes a difference to the sound? She also encourages them to ask questions that they can answer by further investigation.

The teacher notes the way the students go about their inquiry. For example, she watches how systematically they investigate and how thoroughly they observe effects. During the group presentations, the teacher has a further opportunity to observe how the students communicate and explain what they did. She also notes what words they use.

Then, the teacher asks each student to select one instrument and write and draw their thoughts about it, how it makes sound, and how they hear it. Later, the teacher collects these products and studies them for evidence about the students' understanding of sound, their use of evidence, and their reasoning process. From this, the teacher decides on the appropriate next steps for the students—whether they are ready to move on to other investigations of sound or need to consolidate ideas about how sound is created and how it travels to our ears.

What this teacher has been doing in this lesson includes collecting a considerable amount of evidence about the students' ideas and skills. This evidence can then inform the teacher's decisions about next steps in the students' learning. This is assessment. When the assessment is carried out for the purposes of helping teaching and learning (as it is in this example), it is called *formative assessment*. When it is carried out in order to provide a report on where each student has reached at a certain point in time, it is called *summative assessment*.

What to Assess and How to Assess It

Here, we are going to focus for the most part on formative assessment, for two important reasons: first, because it is an integral part of any teaching which attempts to build ideas and skills progressively; and second, because there is solid evidence that effective teaching is characterized by good formative assessment.

Formative assessment is essential to inquiry teaching because the teacher must know what understanding of scientific ideas and process skills the students have already developed in order to decide what is needed to help the children's progress. It is this use of the assessment that makes it "formative." This view of teaching and learning acknowledges the role of the student in his or her learning. No one else can do the learning, but the teacher who wants to help the process will need to know where the student has reached. Gathering information about the learning as an ongoing part of teaching, and using it in deciding next steps, is thus a necessity.

In order to be useful, formative assessment must cover the important outcomes that are intended in inquiry learning. That is, it must be concerned with the process skills and with the understanding of scientific ideas. So the outcomes of inquiry learning have to be identified, and it is essential to know what is meant by progression in each of the skills, attitudes, and areas of understanding. These aspects can't be considered here in detail, but it is useful to list some of them.

The process skills include:

- observing
- explaining (hypothesizing)
- predicting
- raising questions
- planning and conducting investigations
- interpreting evidence
- communicating

The attitudes include:

- willingness to collect and use the evidence (respect for evidence)
- willingness to change ideas in the light of evidence (flexibility)
- willingness to review procedures critically (critical reflection)

The areas of understanding of scientific ideas include:

- characteristics of living things
- processes of life
- energy sources, transmission, and transfer
- forces and movement
- the earth and its place in the universe

Information about all of these intended outcomes of inquiry learning is needed at some point for teachers to use to help progress in learning. Furthermore, experience has shown that what is not assessed tends to be devalued and, in fact, may not even be taught.

Methods of Gathering Information

The teacher whose work was described at the beginning of this essay was using four main methods of gathering information:

- observing students engaged in inquiry
- asking questions designed to probe reasons and understanding
- looking closely at the evidence from class work
- setting special tasks or assignments

Let's look briefly at each method.

Observing Students at Work

Much can be learned about students' skills by observing them at work, particularly if the teacher has a list of things to look for, either as a mental or written checklist. This is one example of a simple checklist a teacher might use to assess understanding in younger children who are working on a particular topic or project.

1. Was at least one relevant observation made (indicated by something said or put on paper)?
2. Was something drawn or described clearly enough for it to be identified by someone else?
3. Were differences between things or from one time to another noticed?
4. Were questions asked about what they observed?
5. Were ideas suggested, perhaps in answer to their own questions?
6. Was some interpretation made of findings by associating one factor with another?

7. Were perseverance and patience shown?
8. Were tasks shared cooperatively?

Based on Harlen and Elstgeest, 1992.

A more elaborate checklist, which embodies a description of development within each aspect of inquiry, helps to identify where students are and what their next step might be. Each successive question indicates a further step in development. This example concerns ability in planning and conducting investigations.

1. Do the students start with a useful general approach, even if details are lacking or need further thought?
2. Do they have some idea of the variable that has to be changed, or what different things are to be compared?
3. Do they keep the same the things that should not change for a fair test?
4. Do they have some idea beforehand of what to look for to obtain a result?
5. Do the students choose a realistic way of measuring or comparing things to obtain the results?
6. Do they take steps to ensure that the results obtained are as accurate as they can reasonably be?

This list is based on Harlen and Jelly, 1997, in which similar developmental lists are suggested for other inquiry skills.

Asking Questions

Observation can give a teacher a certain amount of information about a student's thinking process. But even more information can be obtained when observation is combined with asking questions designed to probe this thinking. The most useful kinds of questions for this purpose are ones that are open, as opposed to closed, and person-centered, as opposed to subject-centered. Open questions invite the student to give his or her view of things ("What do you notice about the bubbles?"), rather than respond to what the teacher suggests ("Do you see the colors in the bubbles?").

Person-centered questions ask directly for the students' ideas ("Why *do you think* the bean plant grew more quickly in the closet?"), rather than focusing on the subject of a particular answer ("Why did the bean

plant grow more quickly in the closet?”). Asking such questions during activities means that evidence can be gathered about students’ understanding, as well as about skills and attitudes.

Looking Closely at Products

The products of students’ inquiry, whether they are drawings, constructions, or pieces of writing, give clues to their thinking and are especially useful in assessing understanding of scientific ideas. These products are more useful if the task is set to elicit the students’ reasoning about what they have found. The following example is a result of a request that a teacher made for a student to be self-critical about her investigation of how far away the sound could be heard when a coin was dropped:

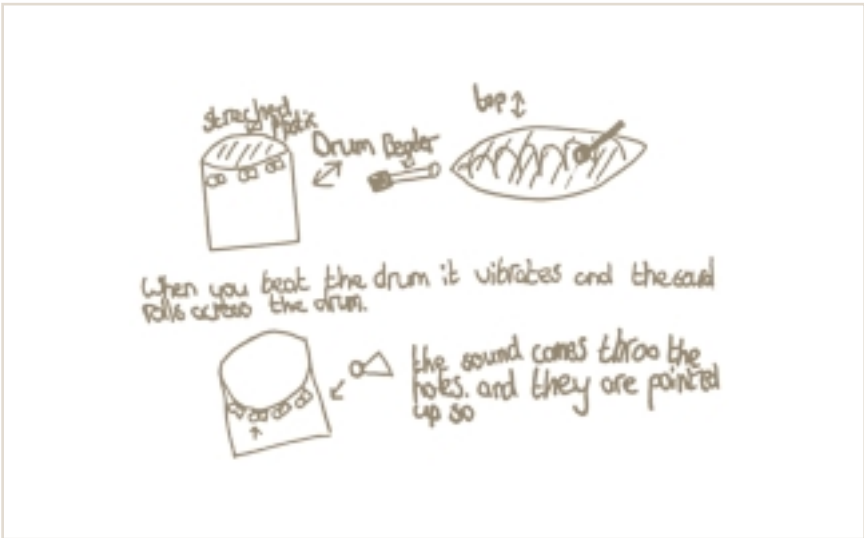
“If I did this again I would try to think of a way to test the sound and not just guess and try to think of more surfaces and try with different coins at different heights. On the sound I have got two ideas, one, see how far away you can here [sic] it drop, and two, get a tape recorder with a sound level indicator.”

Students’ drawing and writing can also provide evidence of their conceptual development. The two figures show examples of students’ work on the subject of sound.

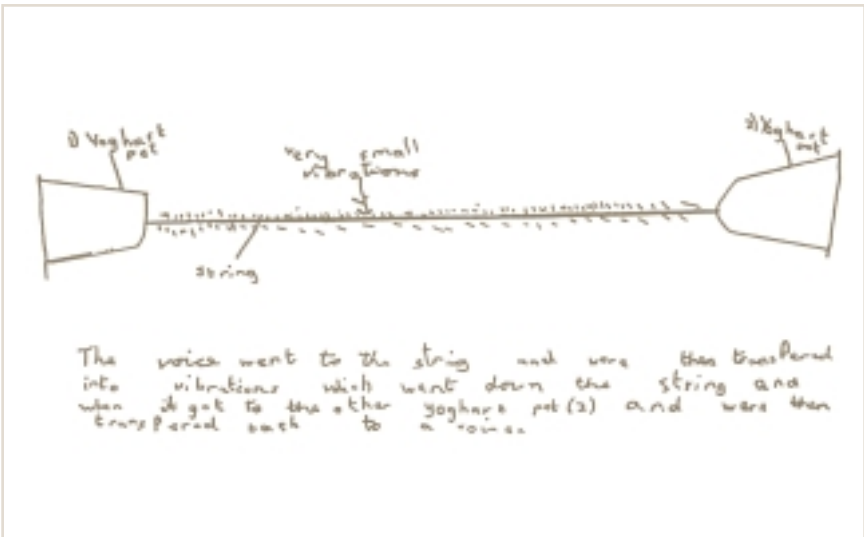
The first figure shows the product of a 10-year-old in response to being asked to write and draw about how the drum makes a noise, and how the sound travels. The idea of sound being associated with vibration is evidently being developed, but this student considered that sound could only travel through air and so had to emerge from the drum through the holes.

In the second figure, the student has been investigating a string telephone. Although the student used the word “vibration,” it is clear that this is applied only to the sound going along the string, and that these vibrations are converted to “sound” in the air.

Both of these examples indicate to the teacher the kinds of further experience and discussion that will help these students’ understanding of ideas relating to sound. Of course, the teacher will be gathering similar evidence from other students in the class and will be able to find out to what extent these ideas are generally held. This information will help to decide what issues should be addressed, and whether it applies to all or just some of the students.



A 10-year-old's representation of how a drum makes a sound, and how the sound travels.



A 10-year-old's representation of sound travelling.

How valuable the products of classroom activities are for formative assessment will depend on these factors: the way the request is expressed, and the extent to which the teacher tries to understand the work and to find clues to points of development.

Students are ultimately responsible for their own learning. Thus, if the assessment information is going to be used formatively—for helping learning—then it is the student who is the user, and the student who needs the information.

In making the request, the teacher must ask for the thinking behind the work. The two figures would have been much less informative had the teacher simply asked the students to draw the instruments. Instead, the request was a much more demanding one: to use writing and drawing to express their ideas. The advantage for the teacher in making this request was matched by the advantage for the students, who would see a purpose for their work, as a contribution to sharing ideas. Similarly, the student who wrote the passage quoted above would see that the point of

the work was improving the investigation, and not just a matter of writing something as a routine.

As the teacher studies the students' work, all the information gathered is potentially helpful, not just the mistakes children make. It may mean talking with the students to clarify meaning, which is time-consuming. But a few pieces of work, valued by both student and teacher, are of far greater value for learning than are many pieces of work to which both teacher and student may give less attention. Discussing work in this way is also an ideal opportunity for teachers to help students share goals of learning, and for the students to begin making decisions for themselves about improving their work.

Special Tasks

Special tasks designed to give students opportunities to use the skills of inquiry can be both hands-on and written. Hands-on tasks can often be adapted to increase assessment opportunities. For example, activities that challenge students to find out “which x is best for y ” could be about soap

solutions for blowing bubbles, paper towels for soaking water, types of salt crystals for dissolving quickly, fabrics for muffling sound, and so on. In all cases, investigable questions have to be identified, and decisions must be made about the variable that should be changed, those variables that have to be controlled, and what has to be measured. Students also have to work out how to put these decisions into operation and how to interpret the results.

Good written assessment tasks are less easy to create than are hands-on activities, but can be adapted from published examples.

Giving Feedback to Students

As we have already noted, students are ultimately responsible for their own learning. Thus, if the assessment information is going to be used formatively—for helping learning—then it is the student who is the user, and the student who needs the information.

Giving a student feedback about a teacher's assessment is an important matter to consider, since it can have both positive and negative effects on learning. For feedback to have a positive effect, it should not incorporate comparisons with other students; that is, each student should be given feedback in relation to his or her progress. Further, the teacher should avoid making judgments about the student's ability. Comments should be closely related to the work and how it can be improved. For example, if a teacher finds that a student has some results about how far away different sounds can be heard, and those results clearly indicate that a fair test has not been made, a teacher might comment, "You have some interesting results there. Are you quite sure that you kept things the same for each of the different sounds that you tried? Why don't you check up on that and see if your results are the same?" This would help learning far more than commenting that the results were wrong, or, indeed, just saying "fine" and not using the work to show the student how to improve it.

Negative effects tend to follow when there is an over-reliance on rewards and competition among students. Research shows that this results in students focusing on those aspects of work that are rewarded; those who don't get rewards often settle for just enough to "get by" (Black and Wiliam, 1998). There is also the danger that low marks may be interpreted by students as meaning that they lack ability, and this may lead them to consider that nothing they can do will change this.

In Conclusion

While the information gathered by the teacher in the scenario at the beginning of this essay was used for formative purposes, all the methods of information gathering that were used can also provide evidence that can be used for summative purposes. It is also possible to design summative tests to assess inquiry skills. Thus, the main difference between formative and summative assessment is not in what information is gathered, nor in how it is gathered, but in how it is used. Formative assessment is used for immediate feedback into teaching and learning, while summative assessment is used to give others information about the students' progress.

Another difference between assessment for formative and summative purposes lies in the involvement of students in the assessment process. If assessment is used to help learning, it follows that the students should have a central role in it. Since no learning can take place without the active participation of the students, it follows that they should share the teachers' aims and understand what is expected of them (Sadler, 1989). Feedback, of the positive kind suggested above, is an integral part of formative assessment.

Sometimes gathering information informally, as in the classroom described at the beginning of this chapter, is not sufficient to assess all of the students' skills. In that case, a teacher may introduce special tasks in order to focus on specific aspects of learning that may not have been observed in the regular work. The process might then seem more like assessment for summative purposes. Indeed there is a continuum, rather than a dichotomy, between formative and summative assessment.

Summative assessment summarizes where students have reached in their development at the end of a topic, or at the end of a year. This forms part of the report that ultimately goes out to parents and to other teachers. It also becomes a piece of the ongoing record of each student's progress. Summative assessment often depends on the administration of tests, but this is not always necessary. If ongoing work has been retained in a portfolio, it can be reviewed and a judgment made in relation to criteria or standards. This will reflect a greater range of skills and understanding than can be covered in a short test.

Assessment for both formative and summative purposes is important in education. But too much emphasis on grades, marks, and levels can obscure assessment for formative purposes, which is integral to effective teaching and learning.

References

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