

Enhancing Inquiry through Formative Assessment

Wynne Harlen

Enhancing Inquiry through Formative Assessment

Wynne Harlen



Institute for Inquiry
Exploratorium
San Francisco, California
www.exploratorium.edu/IFI

Editors: Judith Brand and Ruth Brown
Designer: Oscar Guérin
Production Artist: Alisa Lowden
Photographer: Amy Snyder

Institute for Inquiry® is a registered trademark and service mark of the Exploratorium.

Exploratorium® is a registered trademark and service mark of the Exploratorium.

© 2003 by Exploratorium. All rights reserved.
Exploratorium, San Francisco, CA 94123
Printed in the United States of America

ISBN 0-943451-57-4

Library of Congress Cataloging-in-Publication Data

Harlen, Wynne.

Enhancing inquiry through formative assessment / Wynne Harlen;
editors, Judith Brand and Ruth Brown.

p. cm.

Includes bibliographical references.

ISBN 0-943451-57-4

1. Science—Study and teaching. 2. Inquiry (Theory of knowledge).

3. Active Learning. I. Brand, Judith. II. Brown, Ruth. III. Title.

Q181.H155 2003

507'.1—dc21

2003006483



This material is based upon work supported by the National Science Foundation under Grant No. 9911834. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

Contents

Exploratorium Institute for Inquiry	5
Foreword	6
Executive summary	7
Introduction	13
What is to be gained from formative assessment?	14
Why is formative assessment so important to inquiry learning?	17
What does formative assessment involve?	19
How does formative assessment relate to assessment for other purposes?	29
Why does current practice fail to support formative assessment and inquiry teaching?	33
What actions are needed to improve formative assessment in inquiry teaching?	38
References	41
About the author	43
Appendix. Institute for Inquiry Forum: Supporting Inquiry through Assessment	44

Exploratorium Institute for Inquiry

The Institute for Inquiry is a center for professional development at the Exploratorium. It offers elementary science reform educators in-depth experiences in science inquiry through workshops, seminars, on-line resources, publications, and an intellectual community of practice.

Created in response to widespread interest in inquiry-based science instruction, Institute programs are crafted to provide science-reform leaders with opportunities for exploring, examining, and discussing the nature of science inquiry as it relates to teaching and learning. Through these shared experiences and investigations, the Institute aims to bolster elementary science reform efforts across the country.

Institute programs are designed to enable individuals, schools, and districts to increase their capacity for providing quality science instruction within the context of district-wide reform efforts. To this end, a rich array of programming has been created to meet the wide-ranging needs of educators who serve as professional developers: science resource teachers, curriculum specialists, teachers on special assignment, university faculty, museum educators, administrators, and scientists. A Local Laboratory of schools and classrooms where teachers are engaged in inquiry-oriented science education provides case studies of the theory and practice of inquiry instruction.

Resources on inquiry, and information about the Institute for Inquiry, can be found on the Exploratorium Web site,



The Exploratorium is San Francisco's innovative museum of science, art, and human perception. Its interactive exhibits are designed to puzzle, challenge, and engage museum visitors as they explore natural phenomena and discover science concepts for themselves. Visitors can pose questions, devise possible explanations, and test their ideas through direct experience with exhibits as well as with "What's Going On?" discussions. This inquiry-based learning is the basis of the Exploratorium's philosophy of science education, both on the museum floor and in our work with educators.

Foreword

The Institute for Inquiry hosts periodic Inquiry Forums. These Forums are designed to provide a platform for national reform leaders, researchers, scholars, and policymakers to present exemplary practices and exchange views on critical issues surrounding the implementation of inquiry in schools. Each Forum focuses on a particular theme that serves to advance development and innovation around inquiry.

A Forum held in June 1999, *Supporting Inquiry through Assessment*, considered evidence from research and practice about the role of assessment in teaching and learning. The nineteen participants discussed formative assessment as it relates to inquiry teaching in science, and the changes in classroom practice needed to extend its implementation. (For a further discussion of the Forum and its participants, see Appendix, page 44.)

Wynne Harlen, author of this monograph, was one of the Forum's organizers. The monograph was stimulated by the Forum but reflects Dr. Harlen's thirty years' experience in science education, including her research regarding student learning. (See About the author, page 43.)

We at the Institute for Inquiry think that formative assessment—and its relationship to science inquiry—is a topic of critical importance to our colleagues, and we are pleased to publish this monograph. We hope that it will serve to stimulate discussions by the education, research, and policy communities about the role of formative assessment in science education reform.

We are grateful to the National Science Foundation for their support of this project. We would also like to thank Goéry Delacôte, Executive Director of the Exploratorium, and Rob Semper, Executive Associate Director, for providing institutional support.

LYNN RANKIN

Director

Institute for Inquiry

Executive summary

This monograph sets out research evidence and theoretical points supporting the claim that effective formative assessment can raise student achievement. Formative assessment can improve learning in many subjects, but it has particular relevance to inquiry teaching in science. Due to the nature of formative assessment, however, the benefits cannot be secured without considerable change in education policy and practice. To that end, the final section of this document examines the actions required to bring about these changes.

Formative assessment refers to the gathering and use of information about students' ongoing learning by both teachers and students to modify teaching and learning activities. It has long been recognized as part of good teaching practice and even formalized as such by professional groups such as early childhood education associations. Today, however, there are compelling research results indicating that the practice of formative assessment may be the most significant single factor in raising the academic achievement of all students—and especially that of lower-achieving students (Black & Wiliam, 1998a).

Formative assessment fits particularly well into science inquiry teaching and learning, which aims to enable students to build scientific understanding through students' direct interaction with real situations and materials. For this to happen, teachers need to use information about where students are in relation to learning goals. Stated more bluntly, it is not possible to practice inquiry-based approaches in the classroom without also using formative assessment practices.

Evidence and
arguments in favor of
formative assess-
ment

In a review of research on assessment and classroom learning, Black and Wiliam (1998a) identified and analyzed 250 studies comparing classrooms where formative assessment was and was not practiced. This revealed striking evidence that, on almost every kind of academic measure, students whose teachers systematically applied formative assessment techniques out-

performed similar students who did not receive such treatment. These differences were significant, both statistically and educationally.

There was also evidence that the gain was greatest for lower-achieving students. This exhaustive study leaves the reader convinced that the improvement of formative assessment practices in United States classrooms might be the closest thing to the elusive "magic bullet" that education reformers might find.

In addition to this research evidence, the Institute for Inquiry Forum, Supporting Inquiry through Assessment (see page 44) identified strong supporting arguments based on

- considerations of equity, since formative assessment is not dependent on tests, which introduce bias into measures of achievement
- decreasing the gap in performance among students
- modern views of learning that acknowledge students as active participants in constructing understanding
- the view that improving the communication of goals to students and parents increases students' productive work
- the prevalence in everyday life of this approach to supporting the development of people's skills and understanding

It is widely recognized that the education today's students receive should equip them not just with more facts and skills, but with "the capacity to readily acquire new knowledge, to solve new problems, and to employ creativity and critical thinking in the design of new approaches to existing problems" (President's Committee of Advisors on Science and Technology, 1997).

Such aims are often expressed as "scientific literacy"—a term that, although variously defined, is generally taken to mean a grasp of basic science concepts and the ability to use them to "identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" (Organization for

Formative assessment
in action

Economic Cooperation and Development, 1999). Science education should be taking a central role in developing these capabilities, and in providing the foundation for lifelong learning that will enable new knowledge and skills to be acquired in response to changing circumstances.

According to the National Science Education Standards (NRC, 1996, page 2), "inquiry is central to science learning." This learning can only take place, however, if the teacher knows where students are along the paths toward specific goals. Without this information, teachers cannot identify the next steps that students are capable of taking with understanding. In addition, the more that students themselves are involved, the more likely it is they will be able—and will want—to take these next steps. These aspects of inquiry have been identified as formative assessment.

Formative assessment (assessment for learning) takes place during the course of learning. It is distinct from summative assessment (assessment of learning), which takes place after classroom activities to see what learning has taken place. The process of formative assessment involves the teacher in

- gathering evidence about students' skills, concepts, and attitudes relevant to the goals of learning
- interpreting this evidence in terms of progress toward goals
- deciding the next steps
- finding ways of helping students take the next steps

Involving students in all parts of this process is not only desirable but essential, for the research identifies this as a significant element in successful learning. It's part of the teacher's role to communicate goals to students and offer feedback on how they can continue to make progress. Students need to know the

Formative assessment and assessment for other purposes

goals of their learning; it gives them the opportunity to recognize the goals they have reached and those they need to strive for. This does not deny the teacher's responsibility for helping students' learning but recognizes that it is the students who do the learning—and they do this better if they know the purpose of their work.

Summative assessment is valuable for recording and reporting student achievement at certain times. Summative assessment data are generally obtained by giving tests, but these data cannot reflect the full range of goals of learning. Moreover, there is only disputed evidence that summative assessment improves learning (Linn, 2000). The use of test data for high-stakes school evaluation, combined with the narrow base of the tests used, has a serious backwash effect on the curriculum and on the practice of formative assessment. Teachers inevitably focus on what is tested and, indeed, on the kind of learning that leads to test-taking success. This encourages shallow, surface learning, rather than the deeper learning with understanding that is important in education today (Assessment Reform Group, 2002; Harlen and Deakin Crick, 2003).

Limitations of current practice that inhibit implementation of formative assessment

If we are serious about preparing our young people to become lifelong learners and informed citizens, we must find a way of ensuring that formative assessment is given at least the attention and resources presently devoted to summative assessment. The more we can strengthen formative assessment, the more feasible it will become to make use of evidence of students' learning for other purposes.

Given the imperative to obtain the benefits of formative assessment, we need to consider why it is not more widely incorporated into teaching.

Certainly there are some teachers who do practice formative

Taking action to establish formative assessment as part of regular practice

assessment as part of inquiry-based learning—and examples of good practice were reported at the Forum. At the same time, several aspects of current practice were identified as elements in the failure to implement formative assessment more widely. These are

- a view of education and of science that undervalues the learning that depends on inquiry, and therefore doesn't value formative assessment
- the burden of external high-stakes tests that tend to favor learning of easily assessed factual knowledge and fail to assess the outcomes of inquiry
- the isolation of teachers in their classrooms, and a lack of sharing through "a community of learning" in the school
- the view that there is not the time needed for inquiry, for involving students in assessing their own work, or for other processes involved in conducting assessment to help learning
- the lack of professional development opportunities that would enable teachers to acquire the skills necessary to effectively implement formative assessment
- the lack of such opportunities in preservice courses

Consideration of these factors indicates some of the changes needed to enhance the practice of formative assessment.

There are several steps we can take to help establish formative assessment practices in the classroom. For a start, we can make known the research findings about its effectiveness. (It is worth noting here that the measures used in research studies to detect advances in learning were regular tests of the kind currently used. Thus, the time needed for formative assessment is in fact contributing to learning and success on all measures, including standard tests.) Even more convincing evidence can come from teachers who practice formative assessment—and from the students who have experienced it.

Examples of successful methods and techniques are already available to be captured and disseminated. We need to find ways of encouraging teachers to try incorporating formative assessment into their teaching, and to see for themselves its powerful effect on learning. We can help this process not only by making available already proven approaches, but also by providing resources, examples, workshops, and access to expert practitioners. We can also embed development of knowledge and skills relating to formative assessment in teacher education programs and in professional development, providing examples of student work and models of studying and using student work formatively.

We need to communicate the benefits of formative assessment to parents and others with interests in students' learning as well, and use the information it provides to improve communication between parents and schools. Parents—and others concerned with schools—should know the potential that formative assessment has for improving academic achievement.



Introduction

Formative assessment could also be made “high stakes” by being made a requirement in state inspection or accountability systems. We need to bring to the attention of policymakers the opportunities for raising levels of achievement that are there to be grasped. Funders of research and development (federal grant agencies such as the National Science Foundation, private foundations, government departments such as the U.S. Department of Education, and so on) need to recognize the importance of supporting further work in this promising area now that it has been recognized.

The Forum on Supporting Inquiry through Assessment, which brought together educational researchers, administrators, professional developers, and teachers from the United States and the United Kingdom, identified the strengthening of formative assessment as one of the highest priorities in education at the present time. While reasons for this apply at all ages and to all curriculum areas, the particular application to inquiry science education was the focus of this Forum.

The first three sections of this monograph set out evidence for the claims that formative assessment can improve academic

What is to be gained from formative assessment?

achievement and describe what formative assessment means in practice. This includes considering the involvement of students in self-assessment—a key factor—and illustrating this with examples of practice devised by teachers. Then, assessment that has a formative purpose is compared to assessment with a summative purpose, and a case is made for better balance and articulation between the two. This leads to consideration of a range of factors that can constrain the implementation of formative assessment. The final section identifies some of the actions needed to develop and support formative assessment in inquiry teaching.

There is convincing and incontrovertible evidence that formative assessment increases standards of attainment. This was reported at the Forum by Professor Paul Black of the University of London, from a review of research into the effect of classroom assessment on learning that he had just completed with Dylan Wiliam (Black and Wiliam, 1998a).

Black and Wiliam found that initiatives designed to strengthen formative assessment can enhance student achievement. In fact, the potential improvement is substantially greater than for most other interventions designed to raise academic attainment. Moreover, the evidence showed that lower-achieving students gained more than others. Thus, the spread of attainment can be reduced while the overall level is raised.

The extensive review of over 250 studies that Black and Wiliam carried out ranged from those involving five-year-old students to university undergraduates across several school subjects, and included evidence from many countries. There was an unusual consensus in the findings. However, the authors point out that to secure the often substantial learning gains found in these studies, considerable change in regular classrooms may be required. This is because the gains are associated with the presence of particular features and types of classroom interaction. The study makes these main points:

- All such work involves new ways to enhance feedback between those taught and the teacher, ways which require new modes of

pedagogy—which will require significant changes in classroom practice.

- Underlying the various approaches are assumptions about what makes for effective learning—in particular that students have to be actively involved [active in developing their understanding rather than being passive recipients of information and ready-made ideas].
- For assessment to function formatively, the results have to be used to adjust teaching and learning—so a significant aspect of any programme will be the ways in which teachers do this.
- The ways in which assessment can [positively] affect the motivation . . . of students, and the benefits of engaging students in self-assessment, both deserve careful attention.

(Black and William, 1998b, page 5)

It is important to understand that adding certain activities to current practice will not produce startling gains in student achievement. Rather, some radical change in practice is likely to be needed; there must be some action to counter the constraints identified later in this document that operate against the needed changes in practice.

To add to these research findings, the Forum identified several other good reasons for making the considerable effort that is likely to be necessary. Formative assessment is familiar in daily life outside the classroom. Those who have responsibility for the work performance of others make on-the-spot judgments all the time, often by asking employees to propose a course of action or explain their thinking. In response, they make adjustments to the amount of support or training they provide. This is an ongoing process, not a formal assessment; improvement in performance is the goal. The same thing happens in schools: Teachers constantly have to make judgments about how well students are doing. Formative assessment provides a more formal structure for making these judgments, ensuring that decisions are based on carefully interpreted evidence.

There are other benefits, as well. For instance:

- Formative assessment, which takes place within regular learning activities, takes into account a full range of skills and attitudes without undue dependence on reading and writing skills when these skills are not the ones being assessed. This is in contrast to most classroom tests, which focus on a narrow range of easily tested knowledge and which inevitably depend upon students' reading and writing abilities. Moreover, tests are rarely free of bias in relation to gender, language, and culture, as well as to test sophistication and test coaching.
- As already noted, improved formative assessment has the greatest effect on increasing the learning of lower-achieving students. Not only does this help in providing equal learning opportunities to all sections of the community, but it reduces special needs placements as well.
- In tune with the practice of formative assessment, widely accepted theories of learning emphasize the role of the student in actively constructing understanding. An important part of the process of learning with understanding is linking new experiences, and the ideas used to make sense of them, to previous experiences. The integrated knowledge that results can then be applied in new situations. In contrast, knowledge that is not linked to a general framework of understandable concepts is not

Why is formative assessment so important to inquiry learning?

readily applied beyond those situations in which it was learned and practiced.

- When formative assessment is practiced, students understand not only what they are supposed to be learning, but also how to go about learning it, and they are involved in and committed to learning. They are on the same side as the teacher, working together, rather than being on an opposing side with the teacher dragging the students reluctantly along.
- Formative assessment also generates rich information for parents, who will receive regular reports of progress from their children as well as from their children's teachers. There is a wealth of anecdotal evidence that parents' support for learning can improve as a result. All this means that more productive work is undertaken, leading to increased learning.

The evidence and arguments just described show that, in a number of subjects, formative assessment can increase attainment of all students and bring particular gains to lower-achieving students. In the case of learning science, however, there is an added reason for taking seriously the case for improving formative assessment practice, which follows from considering what students need to learn through inquiry.

It is the nature of learning through inquiry that understanding is built from existing ideas and experience. Inquiry teaching leads students to build their understanding of fundamental scientific ideas through direct experience with materials, by consulting existing resources, consulting with experts, and interacting and debating among themselves (National Science Foundation, *Foundations: The Challenge and Promise of K-8 Science Education Reform*, 1997). In order to promote the construction of understanding through inquiry, it's clear that students need the following:

- to have experiences that are within reach of their existing ideas and ways of thinking
- to have experiences that link to previous ones and to the ideas that help understanding
- to make their own ideas explicit to themselves as well as to the teacher
- to have access to other ideas through books, social interaction, teacher guidance, and the media
- to gather evidence by using inquiry skills to test their own and others' ideas
- to be in control of making sense of new experiences
- to reflect on how their ideas and skills have changed
- to engage in activities that they see as relevant, important, stim-



What does formative assessment involve?

ulating, and valued for themselves, rather than simply for their usefulness in passing tests and examinations

If teachers are to provide such experiences for students, it follows that they need to find and use evidence of students' existing ideas, skills, and attitudes. This implies a clear idea of the goals of learning and of the path of progression toward these goals. It means that teachers have to be able to recognize how far students have come along this path, identify next steps, and know how to help students take these steps. Teachers also need to know how to share the goals of learning with students, and how to encourage them to assess their own work. In other words, formative assessment should be embedded in their teaching.

But there is already a considerable amount of assessment in classrooms. Is this asking for yet more? If not, how is this proposal different from what happens now? These questions will be addressed next.

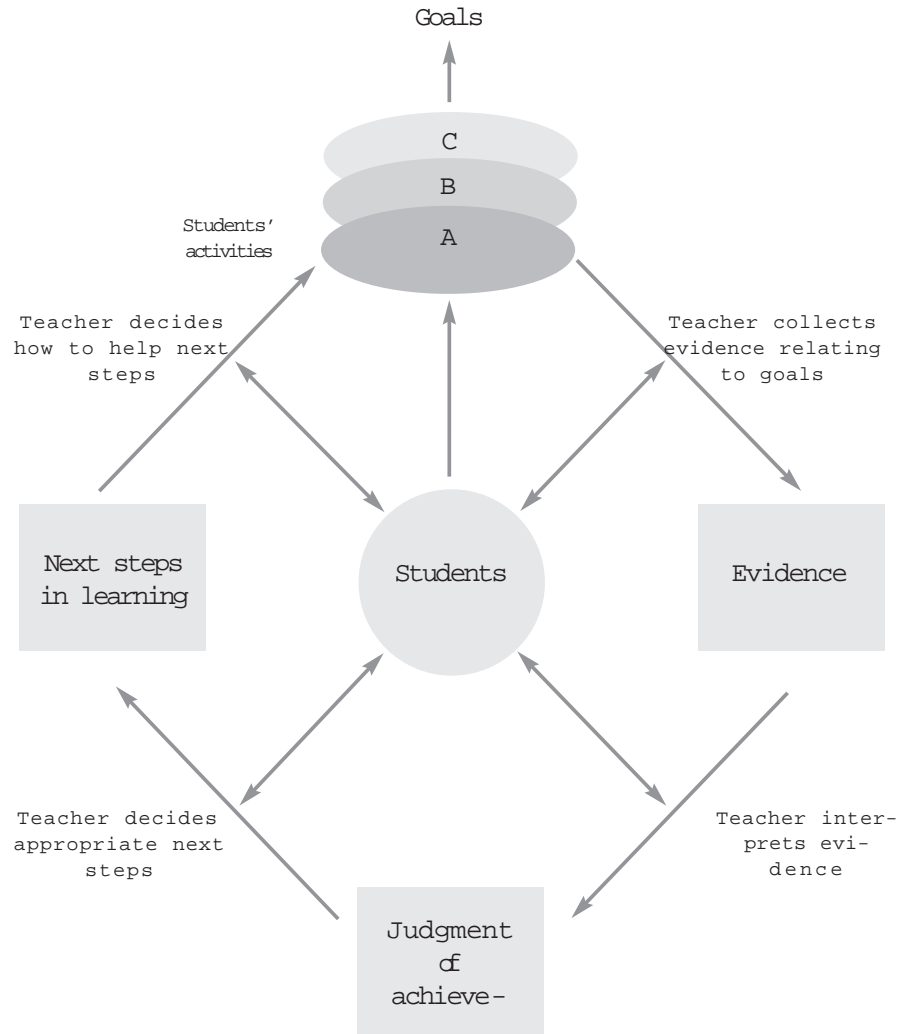
All assessment involves gathering evidence, interpreting it, and using the result in some way. How these things are done depends on the purpose of the assessment. Two of the main

Box 1. Using evidence for feedback in teaching

If the goal for students is to understand how living things are adapted to their environments, Activity A might be one in which students look closely at certain living things and notice where they are and are not found. If students begin to generate testable explanations from their observations, the next activity, Activity B, might be to gather more information about the conditions various organisms prefer (which might include some experimental investigations). If, on the other hand, students do not generate their own explanations, Activity B might be to do

Figure 1

Formative Assessment Cycle



Collecting evidence
of students' thinking

purposes are to help learning (assessment for learning) and to report on the learning of individual students (assessment of learning). These are our main concerns here, but we cannot ignore the use of data about the performance of groups of students for a third purpose—that of evaluating teaching and for school target-setting, since this has an impact on classroom work. We'll return to this point later.

Assessment for learning, or formative assessment, is a procedure for regulating teaching so that the pace of moving toward a goal is adjusted to ensure the active participation of the students. As with all regulated processes, feedback into the system is the important mechanism for ensuring effective operation. Just as feedback to the thermostat of a heating or cooling system allows the temperature of a room to be maintained within a particular range, so feedback of information about learning helps ensure that new experiences are not too difficult or too easy for students. In the case of teaching, the feedback is both to the teacher and to the students.

Feedback to the teacher is needed so that he or she can decide the appropriate next steps and the action that will help the students to take them. Feedback to the students is most effective in promoting learning if it involves them in the process of deciding what the next steps should be, so that they are not passive recipients of the teacher's judgments of their work.

The use of feedback in making decisions means that the process is a continuous one; the various parts can be visualized as a repeating cycle of events (see figure 1, page 20). The example in box 1 shows how collecting evidence during student activities can affect judgments teachers make about taking appropriate next steps.

Box 2. Collecting evidence of students' thinking

One teacher, in planning a lesson on simple circuits, decided to have the students draw on the whiteboard all the circuits they tried to construct, both those that did and those that didn't work. This form of communication gave her an immediate picture of the way the students' ideas were developing and enabled her to work with those who were unsure and needed help in understanding what is essential in a complete

The first part of the process of formative assessment is collecting evidence of students' existing ideas and ways of thinking in the context of an activity. Methods may include the following:

Interpreting evidence

- observing students—listening to how they describe their work, their reasoning for the explanations they give, and so on
- questioning—using open-ended questions phrased to invite students to reveal their ideas and reasoning (for example, "Why do you think it takes more force to stop this toy truck than that one?"; "What do you think is happening when the sugar is put into the water?")
- asking students to communicate their thinking through drawings, artifacts, actions, role playing, and concept mapping, as well as writing
- discussing words and how they are being used

Gathering evidence in these various ways should be part of the lesson, requiring careful thought and planning—not an "added extra." To collect this information, teachers must set tasks that elicit the use of certain skills or the application of specific ideas. The planning may involve a teacher in deciding, for instance, what

Box 3. Gathering evidence from students' writing

After some investigations of camouflage, a teacher asked her fifth-grade students to write down their ideas about why we find polar bears in the Arctic and brown bears in the mountains in America. This is one girl's answer:

"I think that the reason for brown bears do not live in the Arctic is because that the brown bear can not be camouflaged in the Arctic and if they are not camouflaged the bear will be shot and eaten and the fur will be used as coats for the men. It is the same with white bears not living in the mountains they can't hide themselves so they would get shot as well."

From this the teacher could see how the student was using the concept of camouflage and how adaptation was explained in terms

Deciding next steps

questions to ask that will encourage the kinds of thinking and learning that are intended in a particular activity. What are the appropriate forms of communication that will extend the learning and reveal what has been achieved? What pitfalls might there be in choosing appropriate vocabulary (for example, identifying possible words that may be misunderstood, such as melting and dissolving)?

When lesson preparation includes plans for using such methods, there is a double benefit. On the one hand, their implementation ensures that students use and develop skills and ideas; on the other, they give teachers opportunities to assess this development. The aims of teaching and assessment are closely entwined here.

The second part of the formative assessment cycle is interpreting evidence. It is important not to rush into a judgment of students' ideas and skills without carefully considering available evidence. There is useful evidence in almost everything that students do or say—as long as teachers can recognize and carefully interpret it. For formative assessment, expectations for individual students are determined partly by the intended outcomes

Helping students take
the next steps

of the activity, and partly by the past achievement of the student. The judgment of an individual's work is not purely based on the goals achievable through the activity, but also on such things as the recent progress and the effort of the student. So when the information is used to decide how to provide opportunities for further learning, the decision matches the needs of the student.

Helping students test
their ideas

The process of using information to advance learning is the hallmark of formative assessment: It distinguishes formative assessment from assessment for other purposes, such as end-of-course grades. Judging the point a student has reached in terms of expectations will indicate what the next steps should be, provided that the teacher has a firm understanding of the goals of the activity and of the course of development towards them.

Teachers often need help regarding progression in learning. There are various sources that map development, such as Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) and Atlas of Science Literacy (AAAS, 2001), "The NAEP Science Achievement Levels" (National Assessment of Educational Progress, 2002) and the National Science Education Standards (National Research Council, 1996).

Providing access to
more scientific
alternative ideas

Once next steps have been decided, there are various strategies that can be adapted to particular circumstances. They fall into three main categories: helping students test their ideas, providing access to alternative scientific ideas, and enhancing communication and reflection.

Enhancing
communication
and reflection

This includes extending students' experience and linking together specific ideas to make bigger ones. For example, in one fifth-grade classroom, some students observed the "disappearance" of water from three different sources—an open dish in the classroom, a soaked cloth near a window, and a bowl of water left outside. When students were asked to explain this, some were convinced that the loss from the containers was due to some human intervention. Others had different ideas. One wrote "I think the heat or cold makes it go"; another said the water "goes into the air and will turn into clouds." The teacher helped all the students set up investigations to test their ideas. Then, when the students reported their findings, the teacher made sure that they arrived at an idea that "worked" in each of the situations, and an understanding that explained all the examples of evaporation that they could find.

These ideas will come from a range of sources, including the teacher, other students, books, CD-ROMs, and the Internet. Helping students to take them on board may involve the teacher in "scaffolding"—introducing ideas one at a time and in a way that helps children build their understanding toward the scientific view.

Involving students in
decisions about their
own learning

Elementary teachers are often uncertain about when, whether, or how to introduce the scientific view of things to their students. Consequently, students may be left with their own nonscientific ways of thinking when they could be trying out ideas that expand their understanding. The teacher's role in scaffolding is to support students in using an idea that they have not yet made "their own." One teacher, for example, helped her second-graders understand how plane mirror reflections worked by having students throw a ball against a wall at a glancing angle. The teacher invited the students to suppose that light behaves in the same way as the ball. She asked them to use this idea to work out what they thought would

happen if they shone a flashlight towards a mirror at the same angle that they threw the ball. Students could then test their predictions. When the idea of reflection as a change in the direction of light became part of the students' way of thinking, the teacher's scaffolding was no longer needed. The teacher had helped the students make a link that they had not made for themselves but were able to learn from.

This involves discussion and the role of language in the development of shared understandings. For example, when third-grade students set up parallel and series circuits that each used one battery and two bulbs, they noticed that the bulbs in the series circuit were less bright, and they struggled to explain this observation. The students discussed the problem in groups, tracing the circuits with their fingers and examining the lighted bulbs. Seeing the filament of an illuminated bulb led one student to suggest that it seemed to be "on fire," and another to seize on this as meaning that it takes energy from the battery. Together they worked out the idea that the energy had to "push" through both filaments in the series circuit, so the filaments had to share the energy, while in the parallel circuit, each bulb was able to connect to the battery directly.

Why are students at the center of figure 1 (page 20)? The most obvious reason is that the teacher gathers information from the students, as indicated by the outward-pointing arrows. The reason for the arrows pointing to the students arises from both evidence of practice and theories of learning.

The practical reasons were identified in the research studies reviewed by Black and Wiliam, which highlighted the central role

of students in their own learning. The involvement of students in self- and peer-assessment was among the successful approaches in raising achievement. In the studies reviewed, there were examples of successful strategies for self-assessment with students from age five upward.

The theoretical reasons for involving students in decisions

Box 4. Discussing the purpose of activities

A teacher participant in the Forum described how she regularly discusses with her students the purpose of their activities. She sometimes does this in general terms with the whole class at the start, reinforcing the purpose in discussion with groups later and identifying more specific targets to suit individual students. At other times, she does not give her ideas at the start about what is to be learned. Instead, she waits for the students to begin their exploration and then asks them what they could find out. The discussion goes beyond the details of the activities and extends to "What will you be learning if you do that?" The fact that this comes from the students means

Box 5. Using examples

Teachers find it helpful to have standards exemplified by students' work; for similar reasons, these are also helpful to students. Indeed, there is no reason why some of the examples produced for teachers in publications such as New Standards Performance Standards (NCEE & University of Pittsburgh, 1997) should not be shared with students to show what other students have done. This can avoid problems that might arise by discussing examples taken from the work of classmates. Sometimes it is useful to discuss shortcomings as well as the more positive aspects of a piece of work. A collection of pieces

Box 6. Demonstrating what has been learned

A teacher asked the students to make a practical test to give to each other to test their knowledge of simple circuits. The tasks were far harder than the teacher would have given. All the students, those setting the tasks and those responding, not only enjoyed this challenge but extended their learning in the

Feedback on students' work

about their learning derive from general ideas about how people learn. The kind of learning we need to aim for, as has been suggested earlier, is not a matter of absorbing information and ready-made understandings. Instead, it involves the active participation of learners in using existing ideas to try to make sense of new experiences. In this process, ideas that "fit" become more widely applicable and more powerful in helping further scientific understanding.

When any of us try to learn something or improve performance—whether it's a physical activity such as playing a sport, or a mental one such as learning another language—we like to be able to tell how we are doing. We can only assess our progress, though, if we have a clear notion of what we are aiming for. It is the same with students: They need to be aware of the goals of their learning. However, research reveals that, in too many cases, students do not have a clear notion of the purpose of their activities (Black and Wiliam, 1998a). Consequently, classroom activities appear to students as collections of disconnected and often meaningless exercises. To improve student understanding of the purposes of activities, teachers need to find ways of conveying goals and standards of qual-

How does formative assessment relate to assessment for other purposes?

ity. When students know what they should be trying to achieve, they are in a position to “pull together” with their teacher, and teaching becomes more effective.

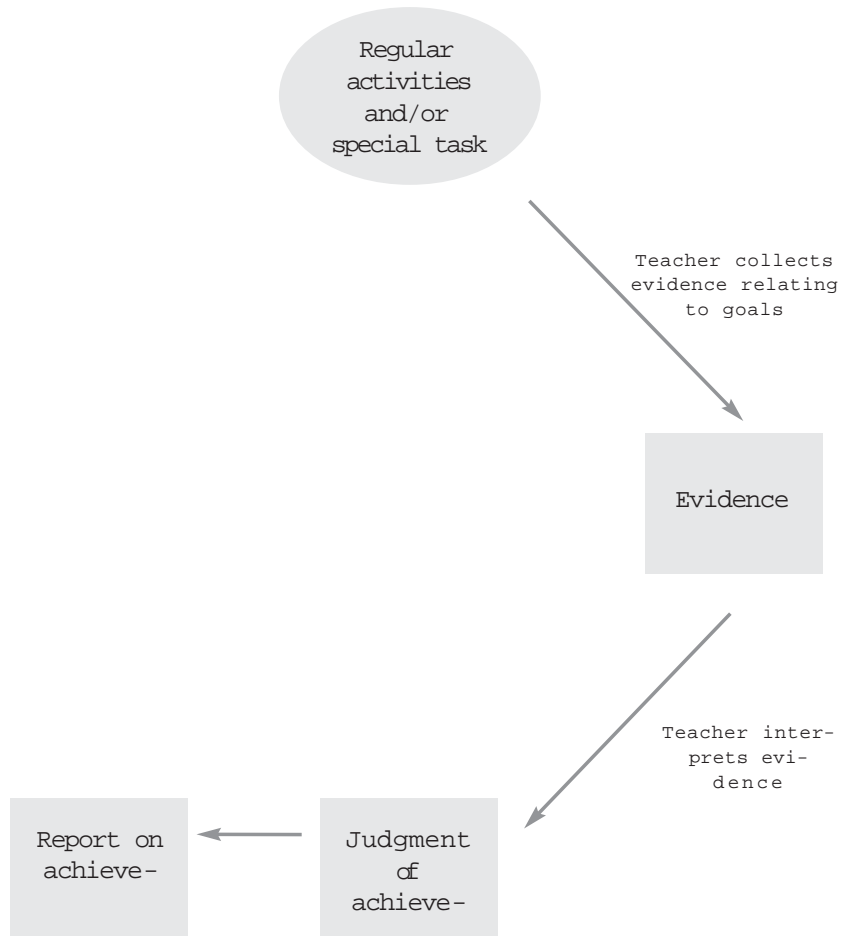
Communicating goals of learning to students is not an easy matter, however, particularly in the case of young students. It will certainly not be possible to do this using the language of official documents. Here are some examples of effective approaches devised by teachers:

- Share with students the purposes of doing certain work (see box 4).
- Use examples of other students’ work to point out aspects that illustrate the standards expected (see box 5).
- Challenge students to show what they have learned—for example, showing how they can make a colored shadow, wire a simple circuit (see box 6), or make a sinking object float.
- Discuss pieces that students select as being their “best work” and ask why students chose them. From this, teachers can determine the criteria students are using, which may not be the ones intended. (For instance, a student might select the best-presented pieces without regard to content.) Then the teacher can take action to communicate the intended goals.

Feedback from the teacher is an important vehicle for helping students know how to improve their work, but it’s crucial that the feedback be the right type. Judgmental comments are seized upon by students: Such comments focus attention on how well students have done and how they compare with others, rather than on what they now need to do to advance their learning. One teacher at the Forum reported having noticed a considerable change in her students’ motivation once she avoided giving any indication of judgment in her written comments on their work. She keeps all judgmental comments in her own records and feeds back to the students suggestions as to what to do next, or questions that help them link what they found to other experiences. The students’ work then becomes a medium for genuine commu-

Figure 2

Summative Assessment



Using assessment data for school evaluation and target-setting

nication between teacher and student about what is being learned.

As we have noted, formative assessment, or assessment for learning, is only one of the purposes of assessing students. Another important purpose is to provide a summary of student achievements at particular times. This is summative assessment, or assessment of learning. This is the basis of reports to parents, other teachers, the students themselves, and increasingly to state authorities.

The aim of summative assessment is to summarize learning achieved at a particular time in a readily communicable form, and so the amount of detail about various aspects of achievement is necessarily limited. Summative assessment does not have the direct influence on student learning that formative assessment does—any impact takes place over a longer term. The process is not cyclical, as is formative assessment, but more as represented in figure 2 (page 30).

There are important differences between figure 1 and figure 2 that arise from the purposes of assessment in the two cases. Formative assessment is both generated and used by the same people—teachers themselves and their students. This is not the case with summative assessment, where information has to be communicable to and usable by others.

Those receiving reports summarizing achievement need to be assured that the information is reliable and comparable from one student to another. This means that the basis for making a judgment has to be the same for each student. It is not appropriate to take effort and recent progress into account in making the judgment; it must be made only in terms of criteria related to the goals.

The need for reliable judgments in summative assessment also reduces the involvement of students in the process. Although some involvement is beneficial (for the same reasons as given in the case of formative assessment), the judgment must ultimately be reliable. It

Harmonizing
assessment for
formative and
summative
purposes

is the teacher's responsibility to ensure fairness in judgments for all students.

Using assessment data for school evaluation is controversial but widespread. It is relevant in the present context because of the likely backwash effect on formative assessment. It involves summarizing information from individual student assessments to form an average score for groups of students. The data may come either from existing summative assessment records or tests, or from tests specifically required and administered for accountability purposes. This use of assessment data is controversial because student performance is a product not just of the school, but of out-of-school influences such as the social and educational home background of the students. One approach that includes these other factors is to take into account student achievement on entering school, and to calculate a measure of "value" added by the school. However, this requires a measure of earlier achievement and leads to more testing of students at very early ages.

The backwash onto the practice of formative assessment arises from the importance given to test data for accountability purposes. Teachers naturally wish to ensure that students will be able to perform well in what is tested and check this by using tests rather than their own judgments. The tendency to do this is accentuated by the practice of using assessment data for measur-

Why does current practice fail to support formative assessment and inquiry teaching?

Views of the process of learning and of the nature of science

ing school performance as an incentive for school improvement. Its most immediate effect, however, is not to improve education, but to focus attention on student achievement on the tests. Indeed, research evidence reviewed by Crooks (1988) confirms that giving tests does not increase student achievement. Linn (2000, page 14) has concluded from studying tests used for accountability that "Assessment systems that are useful monitors lose much of their dependability and credibility for that purpose when high stakes are attached to them. The unintended negative effects of the high-stakes accountability uses often outweigh the intended positive effects." More recently, a review of research on testing has revealed evidence of a negative impact on students' motivation for learning (Harlen and Deakin Crick, 2003).

As a consequence of the attention given to test performance, the use of data collected and used for formative assessment is diminished, and less attention is given to those aspects of teaching that really can raise achievement. What is needed is a better balance between assessment for formative and summative purposes, and more attention given to how they might work in harmony rather than in opposition.

Figure 2 (page 30), for example, suggests that evidence for summative assessment can come from regular activities—and indeed, it could be a summary of the information gathered and used for formative assessment. This evidence from regular activities can be used for summative assessment, but in doing so it is important to make sure of the following:

- it is the evidence of what the students said, wrote, or did that is reviewed, not the judgments of this evidence made for formative purposes (which will take into account student effort and past progress)
- student work is reviewed and compared to the criteria given in statements of standards or indicators
- the work is evaluated in the same way for all students so that the

Box 7. A view of learning science as passive

If a teacher believes that learning is built up from the combination of simple components that students have to memorize, which can then be built into more complex units, he or she will regard all that the students learn as coming from the teacher or other authorities such as textbooks. Students' views will not be highly valued and so there will be no need, in this regime, to gather evidence about them—which is the

Box 8. A view of learning science as active

If the teacher takes a cognitive view of learning, embracing the notion that students are actively involved in making meaning both within and outside the classroom, then he or she will regard the students' understanding as the focus of teaching and the teacher's role as helping to build this understanding. Hence, finding out students' ideas and skills and using this information to help

resulting judgments have the same meaning

Obtained in this way, information about student learning is far richer than that from tests. Moreover, using formative assessment evidence for summative assessment would raise the status of formative assessment and attract the attention that would lead to improved practice.

The strong evidence and arguments in favor of formative assessment reviewed above cannot be ignored if we wish to raise student achievement. In particular, the value to

The pressure of external tests

learning in science is so strong that it is hard to conceive that inquiry-based teaching can take place without formative assessment. Yet, the practice of formative assessment is not widespread, and some considerable changes may be necessary if it is to become part of regular practice. Before turning attention to the actions needed to bring about these changes, however, it is useful first to reflect on current practice and identify factors that inhibit the wider use of formative assessment.

The main inhibiting factors identified at the Forum are related to the following:

- views of the process of learning and the nature of science
- the pressure of external tests
- the pressure of time in the classroom
- limited opportunities for professional exchange within schools
- preservice education and further professional development

Each of these will be considered in turn.

The pressure of time in the classroom

Teachers make the day-to-day decisions that affect the learning opportunities of their students. Of course, they do not do this in isolation; they work within the ethos and program of their schools, using the materials and facilities provided. In turn, the schools are constrained by district and state policies and budgets.

Inside the classroom, however, each student's experience depends on decisions made by individual teachers about, for example, the way in which materials and assessments are used, and about the roles of teachers and students in learning.

Boxes 7 and 8 indicate how two extreme views of learning affect the role of formative assessment. These decisions are influenced by the teacher's view of learning and of the subject being taught (Harlen, 2000).

The view of the subject to be learned (in this case, science) influences the value given to inquiry. An image of science as a static body of knowledge which is value-free, objective, and detached tends to exclude inquiry. With an image of science as a dynamic process for developing understanding about the world, just the opposite is true. Such a view regards science as a human endeavor, depending on creativity and imagination and providing theories that are subject to change in the light of new evidence—all of which is best conveyed through students' participating in inquiry.

The impact that external, high-stakes tests have on teachers' priorities is discussed on page 31. The negative effect of these tests on inquiry teaching follows from their limited range and the fact that they test what is most easily tested in a reliable manner.

In theory, if it were possible to devise tests that validly assess the goals of inquiry-based learning in science, then the curriculum backwash would have a positive effect on inquiry. The notion of "teaching to the test" would then encourage inquiry teaching. However, this is an untested conjecture, and likely to remain so, since inquiry learning outcomes have not been captured in a test of reasonable length and would certainly require more than paper-and-pencil tasks. Moreover, it has been argued (Madaus, 1993) that the intentions of any test can be subverted by determined test-taking practice. The fact that a test exists encourages "surface" or "thin" learning motivated by wanting to be successful on the test rather than by a desire to achieve understanding and deeper learning.

The position remains, therefore, that in order for teachers to promote learning through inquiry, and thus achieve the important outcomes of learning that inquiry offers, we must lift the burden of external tests. The alternative is not an absence of

Limited opportunities
for professional
exchange within
schools

information about student outcomes. That information can be provided by relying more on teachers' own judgments that take into account outside standards.

How classroom time is spent depends on priorities. The points just made about external tests are relevant here since all the activities surrounding the preparation and administration of such tests take a considerable slice of available time and energy. In terms of the important goals of learning, a good deal of this time is unproductive (Assessment Reform Group, 2002).

If we value the development of understanding, skills, and attitudes that will enable today's students to become adults who can make informed decisions about scientific aspects of the world that they influence and that affect them, then it is essential to ensure that teachers can give adequate attention to this development. Of course, knowledge of the physical, biological, and earth and space sciences is needed, but this is knowledge, grounded in inquiry, that leads to a grasp of the "big ideas." It's not just a collection of facts that can be tested by multiple-choice questions. Deep understanding of a smaller number of "big ideas" is far more useful and relevant to future generations than memorizing a larger number of isolated facts could ever be. Less is more, in this case.

Preservice education
and further profes-
sional development

This point has been reinforced by the results of the Third International Mathematics and Science Study (TIMSS, 1995) analysis of textbooks, curricula, and student achievement. United States curricula were criticized for being "a mile wide and an inch deep" (Schmidt, 1997, page 122). Teachers cover more topics, but they spend less time on each than in high-achieving countries, while activities themselves emphasize routine procedures rather than challenging concepts.

If teachers are to meet the educational needs of their students,

What actions
are needed
to improve
formative
assessment
in inquiry
teaching?

Actions by teachers

they need the support that can come from a change in the priorities that drive schools. At the same time, it is important for all stakeholders in education to see inquiry as purposeful, and for the central actors—the students and teachers—to be aware of the learning goals and of progress towards them. Formative assessment, as we have described it, operates to ensure this awareness.

Schools are learning institutions. Right now, while they cater to the learning of students, they fail to cater to the learning of their teachers (Darling-Hammond, 1998). Teachers involved in using formative assessment in inquiry will continually develop new insights into how students learn—and how they can best facilitate student learning. Like other learners, teachers benefit from sharing their insights and other ideas with their peers.

For example, the methods recommended for developing student ideas and involving students in self-assessment, as illustrated on pages 24 and 28, were all originally developed by teachers; these ideas can benefit others if teachers have an opportunity to share them. Greater awareness of these examples of practice can also be used to quell doubts of parents and politicians who might imagine that it is impossible to communicate goals to students or that students are not able to reflect on their learning.

While the opportunity for teachers to easily share ideas would be in the best interests of teachers and students alike, schools are often organized in ways that isolate teachers from each other. The small amount of time available for teachers to meet together is generally taken up by routine administrative tasks. This inhibits professional exchanges about teaching and opportunities for teach-

Actions by principals

ers to gain from each other's ideas, either through discussion or by visiting other classrooms. Professional development leaders at the Forum identified discussion around student work as providing some of the most powerful examples of teacher learning in the full range of teacher professional development models.

Actions by
superintendents and
policymakers

Those entering the teaching profession are likely to bring with them a view of assessment as being a matter of summarizing and grading, rather than as a way of helping learning. This view may well have been reinforced rather than challenged by their preservice education. Hence, few will have entered teaching with the understanding and skills needed to conduct formative assessment as part of inquiry teaching. Unless this situation is changed, more and more teachers will need to look to further professional development courses for help with these aspects of their work. At present, however, such courses are hard to find. More courses that include these elements are needed, as are opportunities for professional developers themselves to attain the necessary understanding and skills.

To improve formative assessment, action needs to be taken on several fronts. Teachers are, of course, the ones who will ultimately implement the changes in the classroom. But they cannot do this unless they have access to relevant professional courses and the approval of their principals, who in turn need the support of superintendents and administrators working within policies that encourage and value understanding generated by inquiry-based science teaching and learning. Some action by each of these players has been indicated in earlier sections. Here, these points are brought together.

Teachers should take action to implement the formative assessment cycle represented in figure 1 (page 20). This will involve the following:

Actions by profes-
sional developers and
teacher educators

- making formative assessment part of their lesson planning (including ways to involve students in assessing their own work, and making clear to themselves and others the goals of inquiry activities)
- systematically gathering evidence of students' learning during teaching by observing, listening, questioning, and discussing concepts and activities with students
- interpreting evidence in relation to class goals and, with students, deciding the next steps in learning
- enabling students to take the steps to advance their understanding and skills by, for example, extending their experience, helping them test their ideas, or providing access to alternative ideas
- involving students in assessing their own work
- reviewing and reflecting on the teaching and learning to inform future work

Principals should ensure that formative assessment is approved and encouraged by

- reviewing school policies on assessment
- providing professional development for enhancing the knowledge and skills teachers need to implement formative assessment



References

- American Association for the Advancement of Science. 1993. *Benchmarks for Scientific Literacy*. New York: Oxford University Press.
- American Association for the Advancement of Science. 2001. *Atlas of Science Literacy*. Arlington, Va.: NSTA Press.
- Assessment Reform Group (ARG). 2002. *Testing, Motivation and Learning*. Cambridge, England: University of Cambridge Faculty of Education.
- Black, P. J., and D. William. 1998a. "Assessment and Classroom Learning." *Assessment in Education*. 5 (1) 7-74.
- Black, P. J., and D. William. 1998b. *Inside the Black Box: Raising Standards through Classroom Assessment*. London: King's College School of Education.
- Crooks, T. J. 1988. "The Impact of Classroom Evaluation Practices on Students." *Review of Educational Research*, 58 (4) 438-48.
- Darling-Hammond, L. 1998. *What Matters Most: Teaching and America's Future*. New York: National Commission on Teaching and America's Future.
- Harlen, W. 2000. *Teaching, Learning and Assessing Science 5-12*. London: Paul Chapman Publishing/Sage.
- Harlen, W., and R. Deakin Crick. 2003. "Testing and Motivation for Learning." *Assessment in Education*. 10 (2). In press.
- Linn, R. L. 2000. "Assessments and Accountability." *Educational Researcher*, 29 (2) 1-16.
- Madaus, G. F. 1993. "A National Testing System: Manna from Above? An Historical/Technological Perspective." *Educational Assessment* 1 (1) 9-26.
- National Assessment of Educational Progress (NAEP). 2002. "The NAEP Science Achievement Levels." National Center for Education Statistics (NCES).

<http://nces.ed.gov/nationsreportcard/science/achieveall.asp>

National Research Council. 1996. National Science Education Standards. Washington, D.C.: NRC.

National Science Foundation. 1997. Foundations: The Challenge and Promise of K-8 Science Education Reform. Arlington, Va.: NSF.

New Standards. 1977. New Standards Performance Standards. Vol. 1, Elementary School. National Center on Education and the Economy & University of Pittsburgh.

Organization for Economic Cooperation and Development. 1999. Measuring Student Knowledge and Skills. Paris: OECD.

President's Committee of Advisors on Science and Technology. March 1997. Report to the President on the Use of Technology to Strengthen K-12 Education in the United States.
<http://www.ostp.gov/PCAST/k-12ed.html>

Schmidt, W. H. 1997. A Splintered Vision: An Investigation of US Science and Mathematics Education. Dordrecht, The Netherlands: Kluwer Academic Publishers.

About the

WYNNE HARLEN began her professional life as a teacher and college lecturer in science and has been engaged in curriculum development, research, and assessment in science for over thirty years. She has a B.A. in physics, an M.A. in education, and a Ph.D. gained through research in education.

After holding the Chair of Science Education and heading the Department of Education at Liverpool University, Wynne became Director of the Scottish Council for Research in Education, a position she held from 1990 to 1999. She is currently Visiting Professor at the University of Bristol. Wynne has worked in over twenty-five countries as a consultant or workshop leader in elementary science education. She also has served on numerous international committees on assessment and standards. She has been chair of the Organization for Economic Cooperation and Development's science expert group for the Program for International Student Assessment (PISA) project since its inception in 1998.

Her research into students' learning has given her a particular interest in using assessment to improve teaching and learning. She has published nineteen books and contributed to thirty others. *Primary Science: Taking the Plunge* (edited by Harlen); *The Teaching of Science in Primary Schools*; *Teaching, Learning and Assessing Science 5-12*; and *Developing Science in the Primary Classroom* (Harlen and Jelly) are widely used in the United States and the United Kingdom.

Appendix

- demonstrating concern for understanding
- showing interest in evidence from students' regular work, and not just from test scores
- creating a community of learning in the school so that teachers can learn from each other

Superintendents and policymakers at all levels should seek to raise the level of practice of formative assessment and inquiry teaching by

- according "high stakes" to learning with understanding and the development of the big ideas of science and of scientific literacy
- promoting these goals of learning to others through policies and persuasion
- providing support for teachers who are willing to try new approaches
- recognizing the important contributions of inquiry teaching for achieving these outcomes
- recognizing the value of formative assessment in all learning
- offering incentives for teachers to improve skills used in formative assessment
- encouraging the review of evidence used in formative assessment for summative purposes, thus reducing the necessity for frequent external tests
- requiring assessment to be addressed in all professional development focused on classroom curricula and instruction
- declaring and defending the value and validity of teacher-based assessments of learning

Those providing courses for teachers should include the kinds of experiences that teachers and future teachers will need to improve formative assessment practice, such as

- providing opportunities for teachers to develop the skills required to implement the formative assessment cycle cited in figure 1 (page 20).

Forum participants
(Affiliations are at the
time of the Forum.)

Doris Ash
Science Educator
Institute for Inquiry
Exploratorium
San Francisco, California

Dennis Bartels
Director
Center for Teaching and
Learning
Exploratorium
San Francisco, California

Paul Black
Professor of Science Education
Center for Educational Studies
King's College
London, England

Judy Wilson Droitcour
Co-Director
KITES (Kits in Teaching
Elementary Science) Project
East Bay Educational
Collaborative
Portsmouth, Rhode Island

Denise Ebisuzaki
Teacher, Grade 3
Clarendon Alternative
Elementary
San Francisco Unified School
District
San Francisco, California

John Frederiksen
Principal Scientist
Educational Testing Service
Concord, California

Adjunct Professor
School of Education
University of California at

Berkeley
Berkeley, California
Linda Gregg
K-5 Administrative Specialist
K-5 Science and Math Center
Clark County School District
Las Vegas, Nevada

Wynne Harlen
Visiting Scholar
Institute for Inquiry
Exploratorium
San Francisco, California

Director
Scottish Council for Research
in Education
Edinburgh, Scotland

George Hein
Senior Research Associate
Program Evaluation and
Research
Group
Lesley University
Cambridge, Massachusetts

Tom Hinojosa
Education Researcher
SRI International
Menlo Park, California

Mildred Howard
Artist
Institute for Inquiry
Exploratorium
San Francisco, California

	(continued)	Elizabeth Stage Director of Science New Standards Oakland, California
Gregg Humphrey Science and Math Teacher Educator Middlebury College Middlebury, Vermont Co-Director Center for Science Education & Professional Development Learning Innovations at WestEd Burlington, Vermont		Lin Tucker Science Staff Developer Cambridge Science Resource Center Cambridge Public Schools Cambridge, Massachusetts
Rhoda Kanevsky Teacher, Kindergarten Powel School School District of Philadelphia Philadelphia, Pennsylvania		Karen Worth Senior Scientist Center for Science Education Education Development Center (EDC) Newton, Massachusetts Instructor Wheelock Graduate School of Education Boston, Massachusetts
Mike Klentschy Superintendent of Schools El Centro School District El Centro, California		
Barry Kluger-Bell Assistant Director for Science Institute for Inquiry Exploratorium San Francisco, California		
George F. Madaus Boisi Professor of Education and Public Policy Center for the Study of Testing, Evaluation and Education Policy Boston College Chestnut Hill, Massachusetts		