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ABSTRACT

Changes in assessment practices are central to ongoing reform efforts in science and mathematics education. The education community is currently focused on new ways to measure, evaluate, and report students' progress toward standards and learning goals. The focus of this publication, using assessment for informing and improving instruction is not only key to effective teaching and learning but also serves as a fundamental building block for other evaluation activities. Embedded in instruction, assessment for this purpose requires a simultaneous focus on what students are doing and learning, and how teachers are guiding the students and facilitating learning. This document includes a summary of research and current literature on the topic, a discussion of effective strategies, an annotated listing of organizations, and print and electronic resources. Contains 34 references. (Author/ASK)

Assessment Strategies to Inform Science and Mathematics Instruction

It's Just Good Teaching

Northwest Regional Educational Laboratory

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It's Just Good Teaching

June 1997

Northwest Regional Educational Laboratory

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Preface

Changes in assessment practices are central to ongoing reform efforts in science and mathematics education. Currently, the education community is focused on new ways to measure, evaluate, and report students' progress toward standards and learning goals. While attention to assessment for this purpose is important and necessary, an equally significant and essential goal is often overshadowed by the flurry of activity surrounding accountability reforms. Using assessment for informing and improving instruction—the focus of this publication—is not only key to effective teaching and learning but also serves as a fundamental building block for other evaluation activities.

Assessment Strategies to Inform Science and Mathematics Instruction follows a format similar to the other documents in the *It's Just Good Teaching* series produced by the Northwest Regional Educational Laboratory's Mathematics and Science Education Center. Intended for use by K-12 teachers, each includes a summary of the research and current literature on the topic, a discussion of effective strategies, and an annotated listing of organizations and resources, both print and electronic. In each publication an attempt is made to contextualize the information for Northwest classrooms. Research in the preparation of *Assessment Strategies to Inform Science and Mathematics Instruction* included interviews with Northwest teachers. Their comments serve to illustrate how teachers are thinking about and using assessment strategies to strengthen teaching and improve student learning.

Using assessment to inform and improve instruction provides teachers with a powerful tool as they explore the alternative assessment arena. Embedded in instruction, assessment for this purpose requires a simultaneous focus on what students are doing and learning, and how teachers are guiding them and facilitating learning. Students' learning and teachers' instruction are mutually dependent—action in one aspect should inform and affect the other. The Northwest Regional Educational Laboratory offers this publication as a resource to support and assist practitioners in their pursuit of effective science and mathematics teaching and learning. Similar to the process described in this document, your assessment informs our actions. We look forward to your continued feedback to guide our efforts to provide meaningful and useful products in support of quality science and mathematics education for all Northwest students.

Kit Peixotto
Director
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June 1997

Introduction

Assessment to inform instruction means that you're using student assessments to make decisions about teaching, to adjust and monitor your teaching style or your activities.

—Judy Vose, teacher, Ferndale, Washington

Using assessment to inform instruction is one of the most powerful tools a teacher has to improve her teaching. It is also one of the most overlooked. Teachers routinely use assessments for a variety of reasons, most often to assign grades and to report students' progress to their parents. However, assessment's real power —its ability to shape and direct classroom instruction—is frequently untapped.

A teacher can learn valuable information about her students' progress and the effectiveness of her teaching methods by examining students' work or products. She can also gain insights into her students' thinking and understanding by observing them both informally (while they are engaged in activities) and formally (during student presentations and conferences between student and teacher).

Although large-scale standardized tests—usually in the form of multiple-choice exams—have dominated the realm of assessment for most of this century, this practice is changing. Today's emphasis on what students are able to do as well as what they know, together with a new understanding of how people learn, has caused educators to look for alternative methods of evaluating student achievement.

Using assessment to inform instruction

Teachers use assessments for various reasons. In the book, *Assessment Standards for School Mathematics*, the National Council of Teachers of Mathematics (1995) identifies several key purposes for using assessment. These purposes include:

- Monitoring students' progress toward learning goals—how is each student progressing in relation to learning goals?
- Making instructional decisions—how can a teacher use evidence about his students' progress to make instructional decisions?
- Evaluating students' achievement—how does each student's understanding at this time compare with the goals that student was expected to achieve?

■ Evaluating programs—how well is the program working in relation to goals and expectations for the students?

Generally, assessment purposes fall into three broad categories: diagnostic, formative, and summative.

Diagnostic assessment. The purpose of diagnostic assessment is to determine, prior to instruction, the student's background experiences, skills, attitudes, and misconceptions. This will help the teacher to evaluate each student's learning needs before instruction begins (Meng & Doran, 1993).

Formative assessment. Formative assessments are often administered during a lesson. They help teachers to ascertain how students are progressing in their learning. Formative assessments often include student demonstrations, written projects, and interviews between teacher and student. Formative assessments are not used for grading purposes, but provide both teacher and student with valuable feedback about the student's progress. Teachers can use this information to make informed decisions about their teaching, such as adjusting the rate of instruction, assigning remedial activities, and planning alternative experiences (Meng & Doran, 1993).

Summative assessment. Summative assessments are most often administered at the conclusion of a lesson, unit, or grading period. They provide a summation of what a student knows at that point in time. Summative assessments are often used for reporting student achievement levels to districts and states, for assigning grades, and for determining whether to place a student in an advanced or remedial class.

Target assessments to obtain specific information. In addition to identifying what students know and can do before instruction begins, and how well they are progressing toward learning goals during instruction, teachers can target assessments to determine specific information, such as (Kober, 1993):

■ How they are progressing toward learning goals

■ Which strategies and thinking processes students use to reach answers or conclusions

■ How well students are integrating new information

■ What motivates students

■ How effective are special interventions

■ Whether a teacher needs to alter her teaching

There is absolutely no way that I can be an effective teacher for each one of my children if I don't know where each one is in his or her learning. I have to understand the child's thinking in order to provide the right kinds of experiences.

—Sue Pack, teacher, Twin Falls, Idaho

Choose the appropriate assessment format. The challenge for teachers is to use the most appropriate assessment format for obtaining information that will serve the desired purpose. Traditional formats of assessment, such as standardized tests and paper-and-pencil exams, will continue to be useful tools for measuring specific educational outcomes. They will be, however, only one of many instruments teachers will use to improve student learning and to adjust their instructional strategies to meet the needs of all students.

Assessments can take many forms, from informal observations and interviews, to student-led conferences and portfolios. A teacher might use checklists to document students' progress, or periodically review students' portfolios and journals to ascertain the progress of their learning.

Some of the methods for collecting information for assessment purposes are familiar activities in the classroom: written tests; observations and interviews; and projects. According to the authors of *Improving Instruction and Learning Through Evaluation: Elementary School Science* (Meng & Doran, 1993), all of these methods are useful and appropriate for some objectives. None are both appropriate and useful for all objectives.

The written test is particularly useful for assessing student achievement on content objectives, the authors say. Performance-based assessments are useful to assess process and/or problem-solving objectives, as well as to assess content knowledge. When administered and recorded in a structured fashion, observations and interviews also provide valuable information about students' process and problem-solving skills, and some of the content objectives. Student projects and reports can be used to evaluate students' knowledge and skills, and their ability to plan, conduct, and report on investigations (Meng & Doran, 1993).

Integrate assessments into instruction. Teachers have always used diagnostic, formative, and summative methods to determine how to help students learn, but with today's emphasis on standards-based instruction, teachers will want to use assessments in a particularly purposeful way by integrating assessments into instruction. By assessing a student's progress before,

during, and after a lesson, a teacher has opportunities to adjust her teaching strategies to meet the immediate needs of her students. By evaluating her students' learning during instruction, a teacher gains insight into the effectiveness of her teaching and obtains valuable information about specific areas of her teaching. Using assessment to inform instruction is an integral process in science and mathematics classrooms where inquiry and teaching for depth of understanding are the focus.

As a scientist you don't plan the next experiment without including information from the previous experiment, and without carefully and thoughtfully designing that experiment. It's the same with planning your instruction.

—Richard Petersen, teacher, Beaverton, Oregon

The national standards for both science and mathematics emphasize the importance of using assessment to guide instruction and to improve teaching, expanding the purpose of assessment beyond accountability and assigning grades. The standards depict assessment as an opportunity for learning—for both teachers and students—rather than an interruption of the learning process. In addition to monitoring student progress and evaluating mathematics and science programs, the standards call upon teachers to use assessment data to plan curricula and improve classroom practices. Teachers use the information for decisions about classroom interactions, how to modify activities to meet the diverse learning approaches of the students, and how to design activities that build on student experiences, cultures, and prior knowledge (National Council of Teachers of Mathematics [NCTM], 1995; National Research Council [NRC], 1996).

To use assessments to inform his decisions about instruction, a teacher will want to monitor his students' understanding and progress in order to design and facilitate instructional activities. He can determine where the gaps are in his students' learning, or where misperceptions are interfering with students' understanding, and he can adjust his teaching methods to rectify these problems (Kober, 1993).

According to Nancy Kober (1993), assessments that are particularly useful for informing instruction have the following features: They measure the processes students use as well as the answers they reach; they measure all of the goals of the curriculum; they address both group and individual activities; they are developed by teachers and include a teacher's professional observation and judgment; and they draw information from multiple assessment sources. Finally, assess-

ments should have a self-evaluation component for both students and teachers.

Make appropriate decisions about instruction. Learning activities that engage students in solving nonstandard problems, and require them to justify their strategies and solutions, can provide teachers with strong evidence of students' learning. Based on this evidence, teachers can then make appropriate instructional decisions that respond to the specific needs of their students (NCTM, 1995).

The *Assessment Standards for School Mathematics* (NCTM, 1995) state that such decisions include:

- Identifying appropriate content, sequencing, and pacing of lessons
- Modifying or extending activities
- Choosing effective teaching methods
- Examining the effects of the tasks, discourse, and learning environment on students' knowledge, skills, and dispositions
- Making instruction more responsive to students' needs
- Ensuring that every student is gaining mathematical [and scientific] power

According to the *Standards*, "The quality of teachers' instructional decisions depends, in part, on the quality of their assessment and their purposeful sampling of evidence during instruction." Teachers will want to blur the lines between instruction and assessment because assessment is an opportunity for learning rather than an interruption in the learning process.

Observing, listening, and questioning are the most common methods for gathering evidence of learning during instruction, and teachers may elect to modify their instruction based on that evidence, state the *Standards*:

> Questioning a few students often leads to a redirection of the lesson for all. The justification for changing the direction of a lesson could come from the confusion ensuing as third-graders attempt to measure their heights with metersticks or from the

excited conversation of high school juniors exploring exponential functions on a graphing calculator. Similarly, a teacher might adjust plans for the week as a result of recognizing that students' responses to a problem are far richer than expected, musing, 'Terrific! I hadn't thought of so many ways to do this problem. I wonder if there are even more. Maybe we should spend some more time on it tomorrow.'

As teachers integrate instruction and assessment, they will want to identify places in the lesson where they can check for specific types of understanding, ask specific questions, or collect work to inform themselves as they make instructional decisions. By combining written products with documented evidence from observations and questions, a teacher will have a more complete picture of students' knowledge and abilities than can be revealed by relying only on tests, quizzes, and assignments that focus on the mastery of procedures or skills (NCTM, 1995).

Assessment strategies

The following assessment strategies are not new, and many teachers will recognize techniques they are already using to evaluate students' achievement. Using these methods to inform instruction often requires just a slight shift in current thinking and practice. When teachers are considering how to provide effective instruction, they will approach assessment with different questions: "What does this tell me about my students' learning? How can I adjust my instruction to address their difficulties and build on their strengths?"

In this approach, assessment does not take place only at the end of a unit but is an ongoing, cyclical process. Teachers monitor student development and respond to the results by adjusting their instruction. Before beginning a unit or lesson, teachers can use assessment data to determine a starting point—what prior knowledge needs to be addressed, what types of activities are required, and how to group students for cooperative learning activities. During a unit, teachers will use assessment to monitor the success of the activities, to diagnose misconceptions that students may be forming, and to determine if students are acquiring the necessary level of understanding and the ability to apply their knowledge. The final assessment activi-

ties help teachers identify areas for further study and plan upcoming units.

You can't get all the information you need from just paper-and-pencil activities. Over the years, I've learned to do different kinds of assessment to obtain more information about the kids and their learning.

—Judy Snider, teacher, Filer, Idaho

Teachers are encouraged to choose the strategies from the following sections that seem to meet their needs and interests. They may want to select one or two methods to investigate and implement (See "Resources" section). As always, each teacher will need to evaluate the activities and adjust them to fit her students and classroom.

Concept maps. Students create concept maps to demonstrate their reasoning and understanding (Stiggins, 1997). Ideas are placed in a diagram and linked by lines and words that indicate relationships between the concepts (see Figures 1 and 2). Other terms for this strategy include mental mapping, concept webbing, and clustering.

Concept maps can be "windows into the minds" of learners, providing a richer view of students' knowledge than tests (Dana, Lorsbach, Hook, & Briscoe, 1992). Concept maps help students organize and represent concepts in a meaningful way. They are also valuable because they are a visual tool for depicting ideas and connections.

Teachers can use concept maps in several different ways. Students can create their own maps individually, which can be useful for identifying individual needs and learning styles and for monitoring each student's understanding.

Concept mapping can be a small group activity with students collaborating and then discussing and comparing how they designed their diagrams. This approach is useful for determining themes and shared misunderstandings. It gives students a chance to sort out their ideas and clarify their thinking together, and it is also an opportunity for peer teaching.

Another approach to concept mapping is as a whole class-activity. Students provide and discuss ideas and the teacher fills in the map. This process is especially useful with students whose writing abilities are not yet well developed. Teachers can use this activity to identify students' questions and areas of interest, a good starting point for a new unit or an inquiry activity.

With modifications, concept maps can be appropriate at all grade levels. Mathematics teacher Bobbye Hoffman Bartels suggests several activities with varying levels of difficulty. Teachers can give students a list of concepts and a map to fill in with the connections and linking words already provided. For a more difficult task, students create their own maps from a list of concepts, determining the connections and the linking words for themselves. Even more challenging is a task in which students generate their own lists of concepts and create their own map (Bartels, 1995).

Teachers can use concept maps as an ongoing assessment of students' learning. They allow teachers and students to exchange ideas about why a linkage is valid or invalid, and to identify links that are missing. The maps help teachers identify misunderstandings about con-

What does this student's map tell you about his understanding of the "food chain?"

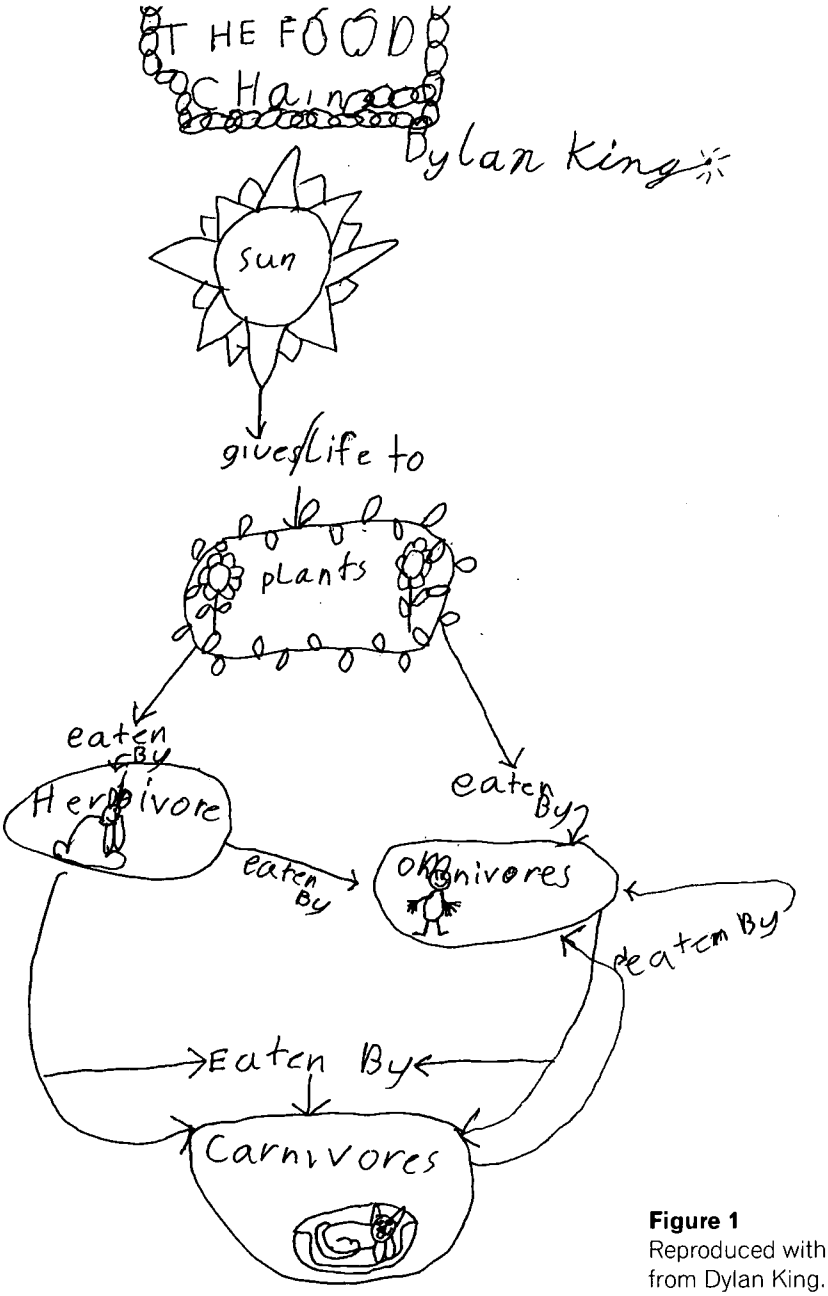


Figure 1
Reproduced with permission from Dylan King.

cepts and the connections between ideas. Teachers can then address students' incorrect conclusions and identify areas for new learning.

At the beginning of a unit, teachers can use concept maps to determine ways that they can connect material to students' prior knowledge and directly address their misconceptions (Novak & Gowin, 1984). In the middle of a unit, concept maps can be used to determine areas that may need additional emphasis, reteaching, or a different approach. Having students complete maps at the beginning and the end of a unit provides documentation of their growth.

Writing activities. Writing activities provide teachers with a variety of information to guide their instruction. Students can express their attitudes and feelings, as well as identify areas they are having difficulty with or particularly enjoy. Teachers can use writing assignments to examine their students' thinking processes and conceptual understanding (Carter, Ogle & Royer, 1993; Kulm, 1994).

Writing about mathematics and science requires students to focus on and internalize important ideas (Miller, 1991). Therefore, writing tasks are a way to determine when students have understood a concept. In addition, the process of writing may help students come to a better understanding of a topic or idea. Teachers may want to extend these activities by having students read and respond to each other's writing.

What insights can a teacher gain by examining this concept map?

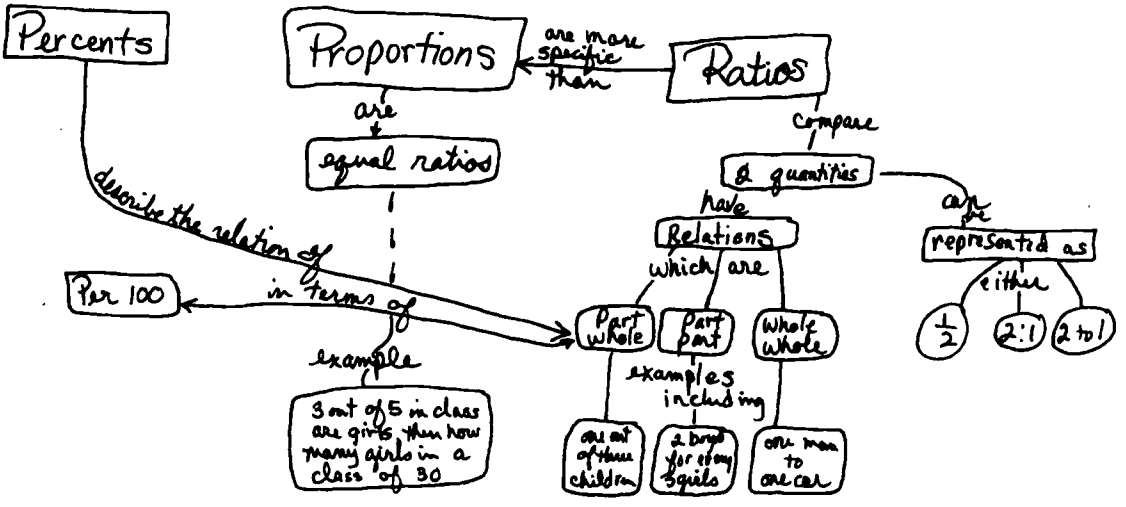


Figure 2
Reproduced with permission from *Mathematics Teaching in the Middle School* ("Promoting Mathematics Connections with Concept Mapping," by Bobbye Hoffman Bartels), copyright 1995 by the National Council of Teachers of Mathematics.

The thing that struck me the most about using writing assessments was how much students clarify the concept when they write.

—Judy Vose, teacher, Ferndale, Washington

Teachers can incorporate writing into mathematics and science in a variety of ways. Journals and notebooks can be a daily or weekly part of class or can be assigned as homework. Individual writing assignments can be used as follow-ups to an activity or a cooperative learning experience.

Journal writing can be free-form or the teacher can provide specific questions or prompts. Teachers might also ask students to keep a notebook for an extended project or investigation, documenting their activities. Students should be encouraged to write thoughtfully to demonstrate their understanding of the activities and concepts. The students should also raise questions, identify problems or concerns, and propose solutions. Notebooks can include an element of self-assessment, allowing students to reflect and evaluate their progress (Cuozzo, 1996).

Math journals are very effective assessments of student learning and are helpful to the teacher in establishing the pace of instruction. At the end of the period I ask students to explain a concept or give them a problem to solve and then have them justify their solutions in their journal. It's like a math diary where students can keep track of their own progress.

—Judy Snider, teacher, Filer, Idaho

Journals can be used to uncover misconceptions or areas of weakness that teachers need to address. It is important for teachers to be able to determine if students are merely manipulating symbols and following rules without really understanding them (Miller, 1991). Journals provide information about areas of difficulty, helping teachers identify students who are having similar problems in order to adjust their plans according to student needs (Potter, 1996).

Writing activities give students who are reticent about speaking in class an opportunity to communicate that is more comfortable for them and therefore more effective (Miller, 1991). Journal writing allows students to express their anxieties about a topic and explain problems they are having.

Although monitoring student journals does take time, journals can be a very efficient way for teachers and students to interact and communicate with one another. They are a form of indirect personal attention. Teachers can come to know their students better as people and as learners, identifying their needs and interests. Teachers who are short on time might respond indepth to several students per week on a rotating basis. In this case, it is important for the students to know that their writing is valued and that the teacher will read their journals, even though he may not respond in writing every week.

Performance assessment. Performance assessments typically focus on the process of solving problems or completing complex tasks. The emphasis is on what students can do, not just what they know. Performance assessments allow students to show how they reach their solutions, explain their answers, and demonstrate their ability to synthe-

An era of standardized testing

As the importance of classroom assessments increases, and the heavy reliance on multiple-choice standardized testing lessens, it is helpful to understand how and why the practice of large-scale testing began. In his book, *Student-Centered Classroom Assessment* (1997), Richard J. Stiggins identifies a period in American history that shaped the philosophy of testing that has prevailed in the United States throughout most of the 20th century. After World War I, immigrants flooded into the United States. As Americans, we wished for a common culture in which we all spoke the same language and shared a national experience. We believed that schools provided the best means for assimilating newcomers into American society, so we created a standard curriculum and made school attendance compulsory.

Students in unparalleled numbers showed up at school doorsteps, and educators scrambled to devise a way to educate them as efficiently and economically as possible. The "assembly line school" was created in which students moved annually from one level to the next. Over time, some students fell behind, creating a growing achievement gap. This practice contributed to the sorting of young people into social and economic segments.

This principle of sorting students was solidified with the invention of a new kind of achievement test: the objectively scored paper-and-pencil test that was used to separate students based on their test score. Because it was thought to eliminate teacher bias and could be mass produced, administered, and scored efficiently, the test was believed to be "scientific." Thus, the realm of assessment was left to scientists or statisticians, and not to teachers.

[Editor's note: This reliance on standardized testing to sort students rested on an assumption that achievement was based on a student's ability and not on a student's effort. One of the most valuable attributes of classroom assessment is that it allows

teachers to understand their students' learning processes, including both the concepts and misconceptions that underlie students' thinking.]

In the 1960s, states began passing legislation that held schools accountable for raising student achievement (Rothman, 1995). Educators turned to standardized tests as a source of relatively reliable data on which to evaluate student achievement. Though publishers indicated in their test guides that the tests were intended to supplement teachers' classroom assessments, standardized tests became the principal measure of educational excellence for decades.

Today, most people believe that a school's mission should be to ensure that students attain core competencies, rather than sorting them. Schools must ensure that students become competent in those skills that will enable them to thrive and to contribute to society.

Research in cognitive psychology has also influenced educators' search for alternative testing methods. According to research, learning is not linear but advances in many directions at the same time and at an uneven pace (Dietel, Herman, & Knuth, 1991). To be a competent thinker or problem solver, people need more than the simple acquisition of knowledge. They need the ability to use skills and strategies, as well as the understanding of when and how to apply them.

Today, many believe that classroom teachers can provide some of the most accurate and appropriate measures of their students' abilities. Large-scale standardized tests will continue to play an important role in assessment. Classroom assessment and alternative formats will contribute additional information about what students know and are able to do. Finally, assessment to inform instruction is another powerful tool for teachers to use to guide their teaching and improve student learning (Stiggins, 1997; Herman, Aschbacher, & Winters, 1992; Mathematical Sciences Education Board, 1993).

(Unless otherwise noted, text is adapted with permission from Stiggins, R. (1997). *Student-Centered Classroom Assessment* (2nd Ed.). Upper Saddle River, NJ: Prentice-Hall.)

size. This assessment strategy provides teachers with information about students' thinking and reasoning (Parke & Lane, 1996).

Performance assessments can provide information that is more instructionally relevant than paper-and-pencil tests. Teachers gain a more complete picture of students' understandings and abilities. This in turn leads to better decisions about student misconceptions and errors, and provides better assessment of the instructional process (Stenmark, 1991).

In order to understand how to help students improve their work, teachers need information on the processes that students use. It is impossible to determine what elements of a teacher's instruction lead to which student results. However, teachers can use performance assessments to develop hypotheses about how their students go about creating an adequate or superior product or performance (Herman, Aschbacher, & Winters, 1992). Using this information, they can modify or develop instructional practices to facilitate growth among all students.

Teachers obtain information on the processes that students use by observing them as they work, by interviewing them about their work, and by examining products that students produce (Stenmark, 1991). Paper-and-pencil tasks that require students to show their work or describe their procedures will also give teachers insights into students' problem-solving tactics.

Teachers can get valuable information about how to help students improve by analyzing how students complete tasks and looking for patterns related to outcomes. Did successful students use a different approach than less successful students? Were the less successful performers hindered by misconceptions and how might they have developed these misconceptions? Where in the process did students run into difficulty? What kinds of errors did they make? Teachers can use this important information to plan future lessons and activities (Herman, Aschbacher, & Winters, 1992).

Interviews and conferences.

Interviews help teachers identify what students have learned and what they have yet to learn. Whether formal or informal, they provide students with personal attention and an avenue for two-way communication. Students can describe what is and is not working for them (Spandel & Stiggins, 1990). Interviews also send the message to students that their thinking is valued by the teacher (Huinker, 1993).

During an interview, teachers can ask students directly about their comfort level, needs, and interests. Interviews are an excellent way for teachers and students to gain an understanding of how

to work together most effectively (Stiggins, 1997). At the beginning of a unit, teachers can use interviews to help identify, select, and organize the content and activities. At the midpoint or end of a unit, interviews provide feedback and help teachers determine if they have successfully fostered student understandings and abilities (Novak & Gowin, 1984).

I think that a teacher will very quickly learn that one form of instruction does not fit all. If you use your assessment wisely, it can become one of the many strategies that you can use to provide an opportunity for students to be engaged in meaningful thought processes related to curriculum, content, and skills.

–Richard Petersen, teacher, Beaverton, Oregon

In order to conduct interviews, teachers can set up a formal time, calling a student aside as the class is involved in other activities. Or the interviews can be informal, asking a student or group some specific questions as they work. The questions should draw the students into thinking out loud, explaining how they arrived at solutions or what conclusions they can make based on collected data and observations (Huinker, 1993).

It is important for students to feel comfortable with the interview process. Students should understand the objective of the interviews and should be aware that the teacher will be taking notes. Students will accept interviews as unobtrusive, routine classroom experiences if they are conducted regularly (Kulm, 1994). Teachers can write down a few key ideas and observations as the student speaks and then expand on their notes immediately after the session is over. For more accuracy, a tape recorder or video camera can be used.

Although teachers will want to establish a list of questions in advance, interviews need not be uniform for all. Teachers do not have to talk about the same things with all students. Teachers will want to customize their questions based on how a student responds. This means that they can gain information not normally available from a less flexible strategy (Moon & Schulman, 1995). It is also not necessary to interview all students about the same lesson or during the same unit. The sessions can be spread out over the course of a grading period or the school

year. Teachers can also use focus-group techniques and interview three or four students together, rather than individually (Kulm, 1994).

I have to keep reminding myself, "Be realistic here: Just work on these three or four kids today, and do a good job with them. Then you can get the next three or four tomorrow."

—Judy Snider, teacher, Filer, Idaho

Interviews can be better sources of information than tests for a number of instructional purposes. They are better for determining students' reasoning and level of understanding; for diagnosing their misconceptions and missed connections; for identifying areas of strength; for discovering students' attitudes toward the subject; and for assessing their ability to communicate verbally about mathematics and science (Huinker, 1993; Moon & Schulman, 1995). Teachers can use interviews to respond directly to students' misconceptions and errors (Thompson & Briars, 1989).

Interviews provide an opportunity for students to think at a high cognitive level. It is suggested that teachers begin a questioning sequence with general questions and proceed to increasingly specific questions. It is important to give students enough time to think through their answers, to reconsider them, and to respond to additional probes (Kulm, 1994).

DeAnn Huinker (1993) of the University of Wisconsin, Madison, suggests that teachers follow up students' responses with probing questions to clarify what they said or did. However, she emphasizes that teachers should do very little talking during the interview. They will need to resist the urge to teach, to give students answers or suggestions, or to pose leading questions.

In her book, *Mathematics Assessment: Myths, Models, Good Questions, and Practical Suggestions* (1991), Jean Kerr Stenmark provides an extensive list of possible interview questions. The questions are formulated to provide specific information about student abilities such as approaches and strategies (What steps did you take?), hypotheses (What do you predict will happen?), communication (How would you explain what you know right now?), flexibility (Have you tried making a guess?), and examining results (How would your method work with other problems?).

Conferences are an opportunity for students to present their work and to gain firsthand knowledge about how their work is assessed. Any disagreements between the student's self-assessment and his or her formal grade can be clarified. Conferences provide important information for instruction because they

set the course for future improvement and growth. Teachers can provide students with strategies that will improve their performance and help them to generate goals and next steps (Darling-Hammond, Ancess, & Falk, 1995).

Debriefing. In debriefing activities, teachers ask students to report extended problem-solving activities or investigations. The students prepare and present reports and then respond to questions from the teacher or classmates. These activities are similar to the processes that mathematicians and scientists use in working together. Debriefings involve more than just reporting answers: Students are required to justify their conclusions and talk about their processes, mistakes or wrong turns, areas of difficulty, and remaining questions.

This information about students' trial-and-error process can provide important information for guiding instruction (Raizen, et al., 1989). "Debriefings enable teachers to see what students know, to understand how they got to know what they know, and to get to know the students as individuals and learners" (Darling-Hammond, Ancess, & Falk, 1995).

The feedback I got from my classroom assessments was that I needed to readjust my teaching in some areas. That is valuable information, but it can be frustrating, too, because I never do anything the same way twice anymore. I'm constantly getting new information, so I'm constantly adjusting and monitoring my teaching methods.

—Judy Vose, teacher, Ferndale, Washington

Debriefings are appropriate as whole-class activities, or teachers can work with students individually or in small groups. The sessions can take place in the middle of an activity, allowing teachers to check progress and redirect the students if necessary. A debriefing may also identify needs for additional background information or skill development.

Debriefings are usually more formal than interviews because students prepare for them in advance. However, teachers can also conduct debriefings as the students work, a technique similar to interviewing. The teacher circulates through the classroom watching students and asking them questions about what they are doing and why: What did you do to get to this point? Why did you do that? What are you planning to do next? (Herman, Aschbacher, & Winters, 1992).

Debriefings help ensure that activities provide students with opportunities for high-quality learning experiences rather than merely a chance to apply rote skills. The students are called upon to

reflect on what they have learned, as well as how they learned it (Darling-Hammond, Ancess, and Falk, 1995). Debriefings require students to put mathematics and science concepts and processes into their own words. They can provide evidence of higher-level thinking skills and depth of understanding.

Observations. Teachers can use the information they obtain from observations to judge students' progress, as well as the success of their instructional approaches. Students' language and behaviors provide information about their interests and their thinking. Observations are also useful for diagnosing difficulties, allowing teachers to design learning experiences that address problems (Moon & Schulman, 1995).

Observing students is a natural part of teaching, but teachers may not have a system in place for documenting their observations. There are a variety of effective methods to accomplish this task: rating forms, narrative descriptions, checklists, and logs. It is recommended that teachers try a variety of formats, adapting the preferred one to their needs (Chittenden, 1991). Teachers can find examples of a variety of tools in the publications listed in the "Resources" section, which begins on page 23.

Teachers will want to have specific ideas about what they are looking for in their observations: levels of understanding, skills and abilities, or types of thinking. Small cooperative groups can be observed as they are engaged in a problem-solving activity or investigation. The teacher moves from group to group as the students work and listens to their conversations, determining what they do and do not understand (Johnson & Johnson, 1990).

This method will not be effective to use with every student every day. Moon and Schulman (1995) suggest that teachers focus on five or six students at a time when opportunities arise. Teachers can then rotate through the whole class over the course of a unit or grading period. Depending on what abilities or qualities are being assessed, teachers may be able to observe students during different activities.

Any good teacher is going to integrate assessment with instruction. Making informal observations while students are actually working can tell the teacher if they are doing the work correctly and, even more importantly, it shows her how they are doing it. The more she studies her students in action, the more she will learn about their growing understanding of the concepts involved.

–Sue Pack, teacher, Twin Falls, Idaho

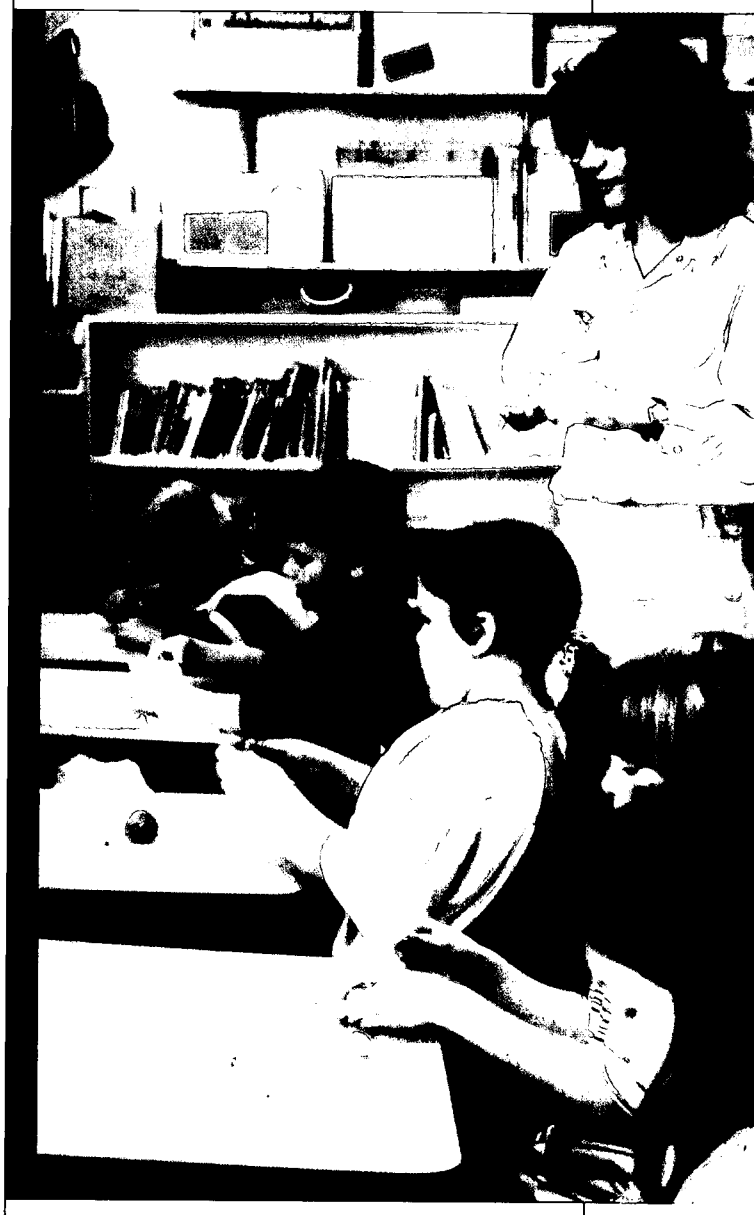
Less formally, teachers may also want to record anecdotes and memorable interactions with or between students as they happen. In listening to students talk with each other, teachers gain information about how students make sense of new information and ideas. They can identify patterns in students' learning preferences that may otherwise go unnoticed (Moon & Schulman, 1995). Teachers can then use this information for ideas on how to present material.

As the kids are working on a group activity, they're interacting with each other, so I listen to what they're saying and I take notes. If I wonder what a student understands or why he did something, then I ask a question, but much of the time I'm just listening to what they're saying and learning from that.

—Judy Snider, teacher, Filer, Idaho

Teachers can also focus their observations on finding out more about their students, using an inquiry approach rather than just checking on student progress. Observations allow teachers to explore the needs, interests, and relationships of their students, as well as gain insights into how individuals learn (Chittenden, 1991).

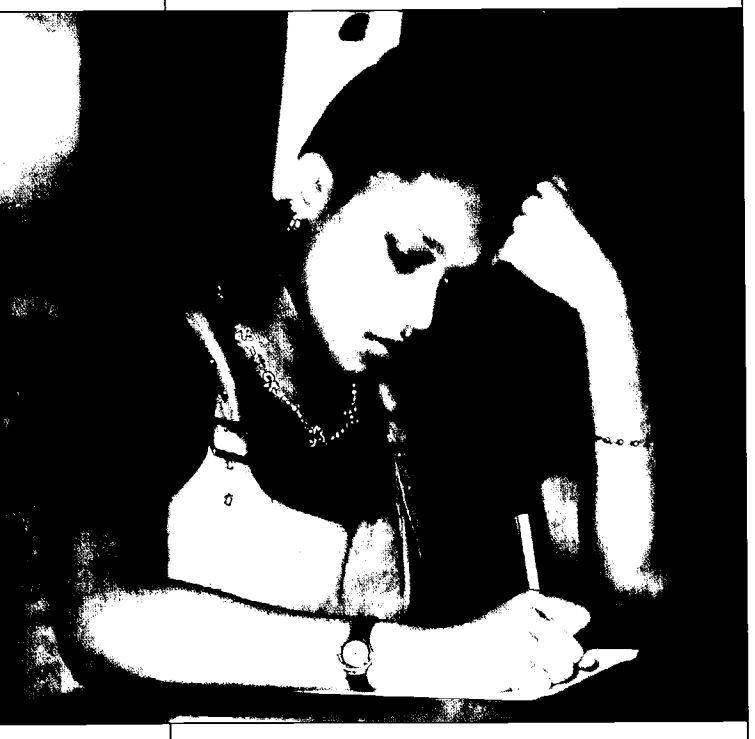
Portfolios. Portfolios are an effective tool for collecting a variety of student work, including the products from multiple assessment strategies. By their nature, they will include different kinds of indicators of what students know and can do, as well as how they think. As an overall picture of learning, portfolios document conceptual understanding, problem solving, reasoning, and communication abilities. The evidence from portfolios is especially rich because it gives an overview of students' progress over an extended period of time (Darling-Hammond, 1996).



In reading what they have written and chosen to put in their portfolios, it gives me information not just on what they like, but what they've learned well—what they've conquered that they didn't know before.

—Judy Vose, teacher, Ferndale, Washington

Portfolios also help teachers to know their students better. When portfolios include open-ended tasks and self-assessments, they become a means of individual expression, and teachers learn more about their students and their preferred learning styles (Moon & Schulman, 1995). More generally, portfolios are a way for teachers to construct their own knowledge of children, how they learn, and how to evaluate that learning (Herbert, 1992).



The process of deciding what to include in portfolios also informs instruction. Teachers must clarify what is valuable for students to learn and what activities are most worthwhile (Collins, 1992; Moon & Schulman, 1995) and therefore must reflect on their teaching practice.

Portfolios are valuable as a way for teachers to share information with each other. At the beginning of the year, teachers can examine the portfolios of their new students to inform their planning process. The portfolios can provide information about students' areas of strength and weakness, interests, and attitudes. They are useful for planning activities and themes for the year, and may help teachers estimate how much time they will need to spend on certain units.

Student self-assessment. Many of the strategies outlined in this publication (journals, interviews, debriefings, and portfolios) incorporate an element of self-assessment for students. Self-assessment allows students to reflect on their learning experiences. Through this process, they become more conscious of their own learning and gain an understanding of their own strengths and weaknesses. They become active participants in evaluation (Moon & Schulman, 1995; Zessoules & Gardner, 1991).

Students' self-assessments help teachers make sense of student efforts and achievements and are an essential part of guiding instruction. Self-assessments improve communication because students become aware of areas in which they are having difficulties and thus are able to articulate their needs to the teacher.

Self-assessment activities are also an opportunity for teachers to gain knowledge of student attitudes. This enables teachers to address the dispositions of their students through their interactions and instruction. They can also help students see how their attitudes affect their performances (Kulm, 1994).

When students reflect on tasks that they enjoyed and tasks that they found difficult it can help teachers understand student learning preferences. Thus, teachers can design activities that address the students' preferences, as well as tasks to build their confidence and comfort level in areas where they have more difficulty.

Teachers can ask students to discuss or write about their experiences as a closing activity: What did you learn today? What were the main points of today's lesson? What are you still confused about? This provides teachers with feedback on the effectiveness of the activities and their instruction. They can also determine what points they need to emphasize and address in upcoming lessons (Kenney & Silver, 1993).

Student assessment of instruction. Another way for students to provide teachers with direct information is through student assessment of instruction. Student input provides teachers with additional evidence in evaluating their effectiveness, identifying strengths, and recognizing areas for improvement. Students can suggest how the teacher can help them learn and indicate what activities or instructional strategies have been most effective (Roscoe, 1992).

My students give me feedback on my teaching. For example, I was talking with some students who thought math was really hard this year. I asked them what made it hard, and they said the most difficult thing had been the vocabulary because it was all new. That is really helpful for me to know. I thought they would be more familiar with it. Sometimes you make assumptions and if the students don't say anything, you don't know the real cause of the difficulties. I found out that it was the vocabulary and not the concept that the students didn't understand. That was really helpful to me.

—Judy Snider, teacher, Filer, Idaho

Students' assessment of instruction provides much of the same information that students provide in self-assessments, and can result in the same benefits. In addition, students are empowered and become more actively engaged when they are involved in determining the direction and atmosphere of the class.

As a closing activity for a lesson or unit, teachers can ask students to identify what they enjoyed most or least, what they liked and didn't like, and why. Students can explain what activities helped to build their understanding and which ones were least useful. Teachers can also ask students about their suggestions for future learning activities.

In addition, teachers can ask students for critiques of their instruction. Some possible questions include: What are examples of things I do or say that make it easier or more interesting for you to learn? What are things that make it harder or less interesting? What might make me a better teacher for you? (Cross & Angelo, 1988).

These activities can be done for individual lessons and units, and at the end of grading periods. Students will become more adept and thoughtful in their answers if this type of assessment is a regular part of class. Teachers must also decide if they want students to produce their evaluations anonymously, individually, in small groups, or as a class.

This type of assessment requires an atmosphere of trust between teacher and students. The teacher must be open to the students' feedback and willing to make changes. The students must feel comfortable about honestly expressing their opinions.

Conclusion

When assessment is used to guide instruction, it becomes another opportunity for learning, rather than an interruption. Drawing on information from a variety of appropriate sources, teachers make decisions about instruction as learning proceeds. This complex process calls for advance planning and an approach that includes inquiry and reflection. The following pages contain a list of resources that teachers can use to help them implement assessment to inform their instruction.

Resources & Bibliography

Note: All books listed in this section are available through NWREL's Mathematics and Science Education Center lending library.

Resources for further reading

Darling-Hammond, L., Ancess, J., & Falk, B. (1995). *Authentic assessment in action: Studies of schools and students at work.* New York, NY: Teachers College Press.

Case studies depict how five schools have developed "authentic" performance-based assessments and how this has influenced teaching and learning experiences.

Herman, J.L., Aschbacher, P.R., & Winters, L. (1992). *A practical guide to alternative assessment.* Alexandria, VA: Association for Supervision and Curriculum Development.

This guide offers ideas on the creation and use of alternative assessments, with a process model that links assessment to curriculum and instruction.

Huinker, D.M. (1993). Interviews: A window to students' conceptual knowledge of the operations. In N.L. Webb & A.F. Coxford (Eds.), *Assessment in the mathematics classroom: 1993 yearbook* (pp. 80-86). Reston, VA: National Council of Teachers of Mathematics.

A collection of articles addressing assessment techniques, managing assessment, and issues pertinent to classroom assessment.

Kulm, G. (1994). *Mathematics assessment: What works in the classroom.* San Francisco, CA: Jossey-Bass.

This book is designed to help teachers plan and implement alternative assessment in the classroom.

Moon, J., & Schulman, L. (1995). *Finding the connections: Linking assessment, instruction, and curriculum in elementary mathematics.* Portsmouth, NH: Heinemann.

This book provides a model for integrating assessment with instruction and guided opportunities to practice and reflect on the assessment process.

National Council of Teachers of Mathematics. (1995). *Assessment standards for school mathematics.* Reston, VA: Author.

Four purposes of assessment are discussed, including making instruction decisions. Vignettes and student work samples provide useful examples and illustrations of the assessment standards in practice.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

The standards identify essential characteristics of exemplary assessment tasks, practices, and policies.

Raizen, S.A., Baron, J.B., Champagne, A.B., Haertel, E., Mullis, I.V.S., & Oakes, J. (1989). *Assessment in elementary school science education.* Washington, DC: National Center for Improving Science Education.

This report addresses issues in assessment: assessment of student learning, assessment of programs, and improvement of assessment.

Regional Educational Laboratory Network Program. (1994). *Toolkit for professional developers: Alternative assessment.* Portland, OR: Northwest Regional Educational Laboratory.

This collection of professional development activities and support materials focuses on alternative assessment.

Romberg, T.A. (Ed.). (1995). *Reform in school mathematics and authentic assessment.* Albany, NY: State University of New York Press.

This book proposes models that give teachers a wealth of nontraditional assessment strategies and concrete ways to obtain measures of both group and individual growth.

Stenmark, J.K. (1991). *Mathematics assessment: Myths, models, good questions, and practical suggestions.* Reston, VA: National Council of Teachers of Mathematics.

This resource is a collection of examples of various assessment techniques that focus on student thinking.

Stiggins, R. (1997). *Student-centered classroom assessment* (2nd Ed.). Upper Saddle River, NJ: Prentice-Hall.

This book includes step-by-step methods for developing effective assessments, integrating assessment into the teaching/learning process, and involving students productively in the assessment process.

Organizations

American Association for the Advancement of Science (AAAS)
1200 New York Avenue, N.W.
Washington, DC 20005
(202) 326-6400
http://www.aaas.org/

A nonprofit, professional society that provides a variety of programs, publications, and resources, including information on alternative assessment and curriculum standards in science.

Assessment Training Institute
50 S.W. Second Avenue, Suite 300
Portland, OR 97204-2636
(503) 228-3060
(800) 480-3060
Fax: (503) 228-3014
E-mail: ati@assessmentinst.com

The institute offers guidance in sound assessment practices through consultation, regional seminars, national conferences, and print and video training materials.

Association for Supervision and Curriculum Development (ASCD)
1250 N. Pitt Street
Alexandria, VA 22314
(703) 549-9110
(800) 933-2723
http://www.ascd.org/

ASCD coordinates, develops, and publishes print and video resources related to assessment.

The Center on Learning, Assessment, and School Structure (CLASS)
65 S. Main Street, Building B
Pennington, NJ 08534
(609) 730-1199
Fax: (609) 730-1488
E-mail: classnj@aol.com
http://www.classnj.org/

CLASS helps educators build schools around students' needs. The center provides consultations, professional development activities, and a variety of resources on student assessment and curriculum design.

Eisenhower National Clearinghouse for Mathematics and Science Education
The Ohio State University
1929 Kenny Road
Columbus, OH 43210-1079
(614) 292-7784
(800) 621-5785
E-mail: info@enc.org
http://www.enc.org/

The clearinghouse is a national information source for K-12 mathematics and science teachers, providing curriculum resources, a monthly list of outstanding Internet sites, thousands of classroom-ready lessons and activities, and links to other Web sites.

EXEMPLARS: A Teacher's Solution
RR1 Box 7390
Underhill, VT 05489
(800) 450-4050
http://www.exemplars.com/index.html

Exemplars assists teachers in implementing authentic assessment and mathematics and science standards in their classrooms.

Lawrence Hall of Science
University of California
Berkeley, CA 94720
(510) 642-4193

This center for teacher education, research, and curriculum development publishes materials and assessment instruments in science.

National Council for Teachers of Mathematics (NCTM)
1906 Association Drive
Reston, VA 20191-1593
(703) 620-9840
(800) 235-7566
Fax: (703) 476-2970
http://www.nctm.org/

A nonprofit professional association dedicated to the improvement of mathematics education for all students. NCTM regularly publishes information on alternative assessment and curriculum resources.

National Science Teachers Association (NSTA)
1840 Wilson Boulevard
Arlington, VA 22201-3000
(703) 243-7100
Fax: (703) 243-7177
http://www.nsta.org/

A professional organization committed to promoting excellence and innovation in science teaching and learning for all, NSTA publishes journals and books, and conducts conventions.

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The Northwest Regional Educational Laboratory provides leadership, expertise, and services to education, government and community agencies, and business and labor, primarily in the states of Alaska, Idaho, Montana, Oregon, and Washington.

Assessment & Accountability Program
Judy Arter, Unit Manager
(503) 275-9562
E-mail: arterj@nwrel.org
http://www.nwrel.org/eval/

The Assessment & Accountability Program collects, reviews, and offers instruments for alternative assessment in science and mathematics. Its database of alternative assessment instruments, resources, procedures, and annotated bibliographies is offered online.

Mathematics and Science
Education Center
Kit Peixotto, Director
(503) 275-9594
E-mail: peixottk@nwrel.org
http://www.nwrel.org/psc/same/

The center provides resources and services in support of effective curriculum, instruction, and assessment. A lending library of books, videos, and other materials on a variety of topics, including inquiry-based teaching, equity issues, education reform, standards and assessment, and effective instructional practices complements other products and services.

Science and Mathematics Consortium for Northwest Schools (SMCNWS)
171 N.E. 102nd
Portland, OR 97220-4169
(503) 760-2346
http://www.col-ed.org/smcnws

One of 10 regional Eisenhower consortia, the SMCNWS disseminates promising programs, practices, and materials, and provides technical assistance and training in support of state and local initiatives for quality science and mathematics education. For a list of assessment resources, see: http://www.col-ed.org/smcnws/assessment.html.

Online resources

Classroom Compass Assessment—A Window to Learning
http://diogenes.sedl.org/scimath/compass/v02n02/welcome.html

Southwest Educational Development Laboratory's online newsletter includes examples of activities that illustrate each issue's theme. The spring 1996 issue examines assessment as an integral part of the learning cycle. A resource list completes the issue.

ERIC Clearinghouse on Assessment and Evaluation
http://ericae2.educ.cua.edu/main.htm

This site contains links to other Web sites, a listserv on assessment and evaluation, and allows searching of the ERIC database and three assessment instrument databases.

Math Forum Assessment in Mathematics Teaching
http://forum.swarthmore.edu/mathed/assessment.html

The forum supports teachers, students, and others with an interest in mathematics. The site provides extensive links to books, articles, and other Web sites related to mathematics assessment.

Pathways to School Improvement
http://www.ncrel.org/sdrs/pathwayg.htm

The North Central Regional Educational Laboratory produces "Critical Issues" sections that provide practical, action-oriented summaries of best practices, research, descriptions of schools that have successfully addressed critical issues, and lists of materials to support change. For "Integrating Assessment and Instruction in Ways that Support Learning," see Critical Issues in Assessment at http://www.ncrel.org/sdrs/areas/as0cont.htm

The Regional Alliance for Mathematics and Science Education Reform Hub Assessment
http://ra.terc.edu/hub/regional_networks/cia/assessment.html

The Regional Alliance's assessment page provides links to resources for alternative assessment.

Resources for specific strategies

Concept maps

The Concept Mapping Home Page
http://www.to.utwente.nl/user/ism/lanzing/cm_home.htm

This site explains how concept mapping can be used for many purposes, including assessment. Illustrations, concept mapping software, additional links, and numerous references are provided.

Problem Solving: Concept Maps
http://cotf.edu/ETE/concept.html

The Exploring the Environment (ETE) site outlines the steps to constructing a concept map, and provides examples and a list of other resources.

Writing activities

Countryman, J. (1992). *Writing to learn mathematics: Strategies that work.* Portsmouth, NH: Heinemann.

This book describes writing activities teachers can use to enhance the learning and teaching of mathematics.

Saul, W., Reardon, J., Schmidt, A., Pearce, C., Blackwood, D., & Bird, M.D. (1993). *Science workshop: A whole language approach.* Portsmouth, NH: Heinemann.

Dana Blackwood's chapter, "Connecting Language and Science Assessment," covers a variety of assessment strategies and instruments.

Scott, J. (Ed.). (1993). *Science & language links: Classroom implications.* Portsmouth, NH: Heinemann.

This book examines the links that exist between science and language learning and teaching. The book also provides teachers with suggestions and ideas for using different techniques.

Performance assessment

Blum, R.E., & Arter, J.A. (Eds.). (1996). *Handbook for student performance assessment in an era of restructuring.* Alexandria, VA: Association for Supervision and Curriculum Development.

Section IV, "Aligning Assessment with Curriculum and Instruction," presents papers on what it means to integrate assessment and instruction.

McCain, R. (1997). Assessment practices in mathematics: Outdated assessment tools are simply not good enough. *The Journal of the New England League of Middle Schools, 9*(4), 33-36.

The article explores various strategies, including interviews, observations, portfolios, performance assessment, self-assessment, and student writing.

OERI Consumer Guide: Performance Assessment
http://inet.ed.gov/pubs/OR/ConsumerGuides/perfasse.html

This Consumer Guide is produced by the Office of Educational Research and Improvement (OERI) of the U.S. Department of Education for teachers, parents, and others interested in current education themes.

Interviews & conferences

Corwin, R.B. (1996). *Talking mathematics: Supporting children's voices.* Portsmouth, NH: Heinemann.

This book includes materials to support teachers in developing a culture of inquiry and communication in their classrooms, including how talk can inform instruction and practical ways to encourage and support discussion.

Garland, C. (1988). *Mathematics their way: Summary newsletter.* Saratoga, CA: Center for Innovation in Education.

This newsletter includes Teacher Reference Cards which list materials needed for assessments, any preparation necessary, suggested questions, procedures, and possible extensions.

Observations

Baratta-Lorton, M. (1976). *Mathematics their way: Black-line masters.* Palo Alto, CA: Addison-Wesley.

This resource contains numerous "observation sheets," informal record-keeping devices used to document children's progress.

Portfolios

Electronic Portfolios: A New Idea in Assessment
http://ericir.syr.edu/ithome/digests/portfolio.html

Anna Maria D. Lankes describes the elements of portfolios and how technology is helping with the creation and management of this form of alternative assessment.

NEA Professional Library. (1993). *Student portfolios.* West Haven, CT: National Education Association.

This collection of articles discusses how teachers changed their assessment practices by using student portfolios in their classrooms.

Resources addressing multiple strategies

Hein, G.E., & Price, S. (1994). *Active assessment for active science: A guide for elementary school teachers.* Portsmouth, NH: Heinemann.

This resource encourages teachers to use a range of assessment approaches and describes specific methods.

Parker, R.E. (1993). *Mathematical power: Lessons from a classroom.* Portsmouth, NH: Heinemann.

The author describes methods for integrating the National Council of Teachers of Mathematics standards into classroom practice, including assessment, and addresses observations, learning logs, rubrics, and portfolios.

Rowan, T.E., & Bourne, B. (1994). *Thinking like mathematicians: Putting the K-4 NCTM standards into practice.* Portsmouth, NH: Heinemann.

This book applies NCTM goals to mathematics instruction. Three specific methods of informal assessment are presented: anecdotal records, portfolios, and journals.

Tsuruda, G. (1994). *Putting it together: Middle school math in transition.* Portsmouth, NH: Heinemann.

The chapter on "Assessment Alternatives" presents writing and talking as the core of alternative assessment. Student presentations, portfolios, and a variety of ways to record observations of groups are discussed.

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