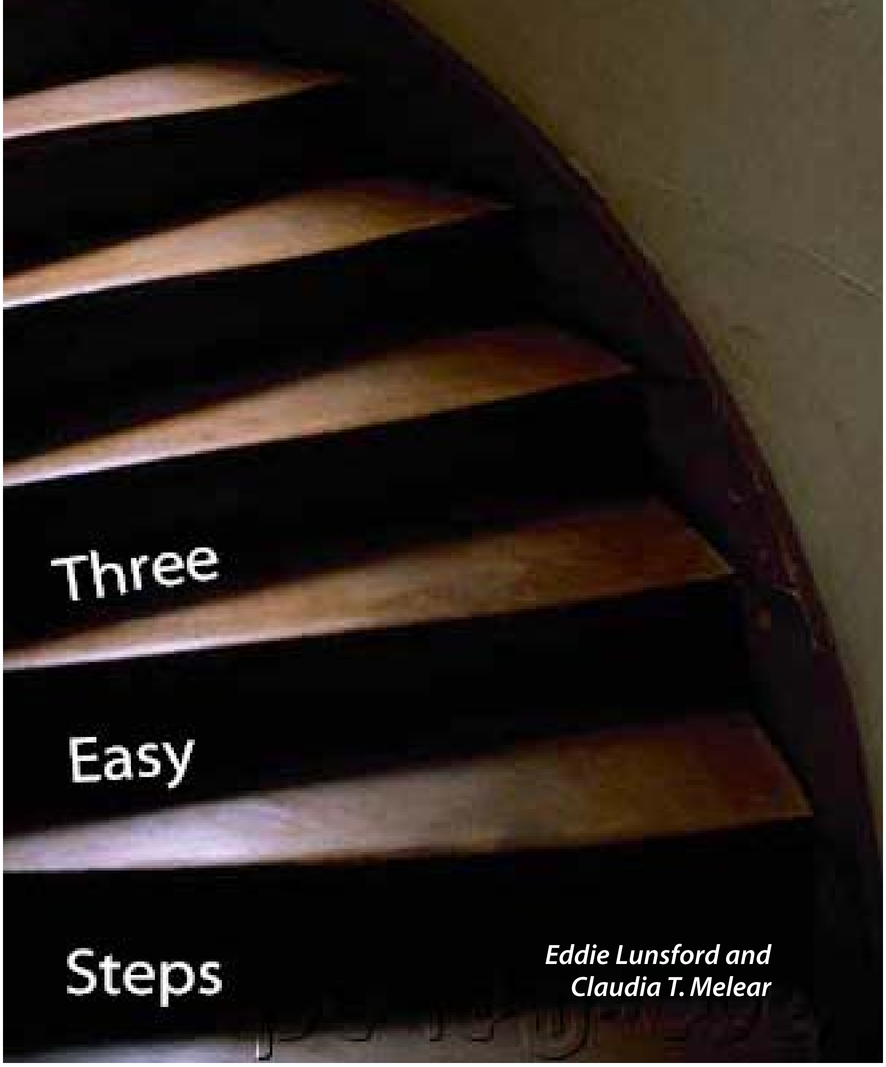
Using Scoring Rubrics to Evaluate Inquiry

This article explores the problem of assigning grades to students engaged in nontraditional activities, especially scientific inquiry. We suggest using scoring rubrics to guide students in their work and to assist teachers with grading. We present the steps involved in the construction of rubrics, and we show sample rubrics.



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Most science teachers are familiar with reform movements in science education. The roots of these recommendations are, in part, grounded in the idea that learning science should be an active, engaging process that mimics the work done by actual scientists. The term *inquiry* or *scientific inquiry* is used to categorize such classroom activities (AAAS 1990; NSTA 1996).

There are differences of opinion about what constitutes inquiry-based teaching and learning. It is probably much easier, and more practical, to list common traits that characterize inquiry than to attempt a definition. Inquiry, for example, affords students the opportunity to engage in the same thought processes as professional scientists. Students engaged in inquiry usually work with poorly defined problems or questions, review the work of others, and carry out their own scientific investigations. They may work as part of a group, use laboratory equipment, decide how to collect and display data and observations, revise their questions, and consider alternative hypotheses and methods (NRC 2001b; Roth 1995).

Teachers may or may not provide students with a research question during an inquiry activity. Further, they may or may not have a specific laboratory skill, content goal, or objective in mind for the inquiry to address. The literature is filled with terms such as *open inquiry*, *community inquiry*, *guided inquiry*, *collaborative inquiry*, *structured inquiry*, *purposeful inquiry*, and *authentic inquiry* to clarify variations on the basic theme (Foster 1998; NSTA 1996; Roth 1995). Inquiry, whatever its form, stands in sharp contrast to the traditional sorts of prepackaged or cookbook lab activities that have driven science classrooms over the years (Ritchie and Rigano 1996).

Most teachers work within a system that requires them to assign a numerical or letter grade to students. Therefore, many are hesitant to embrace scientific inquiry as a mode of instruction because they are not sure how to adequately and accurately assign grades to such work.

This review is an attempt to address that uncertainty, because others have noted that little has been written about assessment of scientific inquiry or about alternative science education assessment in general (Slater, Ryan, and Samson l997; Zachos et al. 2000). We have found a few recent publications that provide teachers with ideas (Pearce 1999; NRC 2001a, 2001b). Doran et al. (1993), for instance, rec-

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ommend routine use of a scoring rubric for evaluating skills, tasks, and behaviors commonly observed during inquiry-based activities.

Through our routine interaction with both new and veteran teachers, we have noticed some common themes. Many teacher-education programs include information about scoring rubrics in their assessment courses. However, new teachers often say they do not use scoring rubrics because they do not know how to construct them to meet their own needs. We commonly find that many veteran teachers have never heard the word rubric. Thus, we have synthesized existing information about assessment and provided classroom teachers with useful suggestions about using scoring rubrics to grade inquiry. We present three easy steps for effectively using scoring rubrics to evaluate student inquiry.

Step One

Define the end product of the inquiry. In the first step, teachers (with or without student collaboration) decide the final end product(s) from an inquiry activity that will be submitted for a grade. Several possible examples are listed below.

Portfolios. Although many of us associate portfolios with artists, they are widely used in various fields. Collins (1992) suggests that science teachers can make portfolios be whatever they want them to be as long as they develop and/or state a clear goal for the portfolio and a purpose for its use. Items that can be included in inquiry-assessment portfolios include observation notes, data, and so forth (LeBuffe 1993). Individual or group work may be included. Artifacts such as notes, videotapes, reports, captions, and reflections may be included as well (Collins 1992).

Scientific research papers. Students may write a formal research paper or laboratory report on their inquiry activity. More than 95 percent of professional scientific research papers are produced by more than one author (Hurd 1998). Therefore, allowing students to jointly write research reports adds an authentic element to the assignment. Some college science teachers require students to write a formal research proposal or a mock grant proposal as well (Harker 1999; Henderson and Buising 2001).

Laboratory practicals and student demonstrations. Carefully planned lab practicals and student demonstrations may be used to evaluate students' inquiry knowledge and skills. Germann and Aram (1996) report that practical exams are a form of performance evaluation that may be used to measure inquiry skills in a way that paper-and-pencil tests cannot. They also suggest that a particular inquiry in and of itself may serve as a lab practical. Examples of inquiry-related skills that may be assessed by way of demonstrations and practical examinations include (but are not limited to) linking theory with evidence, formulating hypotheses, keeping records, using correct or original laboratory materials, identifying cause-and-effect relationships, controlling experimentals, and using parsimony in drawing conclusions (Zachos et al. 2000).

Student journals. Keeping journals is widely done in many content areas, including science (Audet, Hickman, and Dobrynina 1996). Students may make journal entries about inquiry methods, ideas, definitions, and questions. Most are also able to make representations of immediate inquiry experiences that include charts, drawings, and tables (Shepardson and Britsch 2001). As with portfolios, students and teachers have an open playing field when it comes to keeping journals. Journals are flexible, so long as students and teachers know what the working definition of a journal is and how it will be used in class (Shepardson and Britsch 2001).

Concept maps. Concept maps are organizing devices that depict relationships between and among various concepts (terms, observations, categories, processes, and so forth). They may be hierarchical in nature, but some are called network concept maps and do not include hierarchical, ordered, or linear concepts (Ruiz-Primo and Shavelson 1996). Roth (1995) says group concept-mapping

FIGURE 1

Rubric for evaluating a research report.

Criteria	Absent					Excellent
Researchable question clearly stated	0	2	4	6	8	10
Hypothesis clearly stated	0	2	4	6	8	10
Pertinent literature reviewed	0	4	8	12	16	20
Methods, procedures, and terminology clearly described	0	4	8	12	16	20
Data presented in tables, charts, or graphs	0	2	4	6	8	10
At least five published references used	0	1	2	3	4	5
References cited in paper	0	1	2	3	4	5
Bibliography included	0	1	2	3	4	5
Good grammar and punctuation used	0	2	4	6	8	10
Paper turned in on time	0	1	2	3	4	5
Maximum score = 100 points				Your score = ________		

FIGURE 2

Rubric for evaluating a portfolio.

Criteria	Absent to poor, 0 to 10 points	Fair, 11 to 15 points	Good, 16 to 24 points	Excellent, 25 points
Visual presentation of portfolio	No use of color, no artwork, no attention to presentation	Use of some color, some artwork with little attention to detail	Some use of color and artwork; portfolio could be made more attractive with extra attention to detail	Extensive use of color and art and portfolio is attractive
Packaging of portfolio	Portfolio not housed in a folder or container	Portfolio placed in folder or container but not organized or labeled	Some organization by sections and some labeling	All items in portfolio clearly labeled and organized by sections
Scientific inscriptions	None or fewer than 5	5 to 10 included	More than 10 included; some clearly labeled and dated	More than 10, all clearly labeled and dated
Evidence of multiple trials and adequate sample size	None included or only a statement that these issues have been addressed	Evidence that experiment was repeated once with a minimal sample size	Evidence that experiment was repeated two to three times with a minimal sample size or with an adequate sample size	Evidence that experiment was repeated two to three times with an adequate sample size

sessions are perfect complements to group inquiry. They provide a valuable focal point for discussion. Concept maps are known for their flexibility as both learning instruments and assessment tools (Quinn, Mintzes, and Laws 2003).

Other inquiry assessment techniques. A few other methods for grading inquiry are noteworthy. Students can present research findings in the form of seminars (Audet, Hickman, and Dobrynina 1996), press conferences, or news articles for the school or community newspaper. They can also construct bulletin boards or write pamphlets about their work. Pamphlets may be distributed at school or in the community. Professors may interview individual students or student groups to determine all or a portion of a grade on a particular inquiry activity. Student-made inscriptions also hold much promise for the assessment of inquiry activities. These inscriptions may include any graphical, photographic, written, or other types of documentation concerning the planning, execution, or conclusion of an inquiry-based activity (Lunsford 2002/2003).

Step Two

Decide criteria and weight. Rubrics focus on quantification by listing expected tasks, behaviors, and skills and setting standard levels at which students must perform. Point are assigned based on the level at which each criterion is demonstrated (Enger and Yager 1998). Rubrics help students know what is expected of them and encourage teachers to think carefully about their instructional goals. A well-designed rubric eliminates or reduces guesswork on

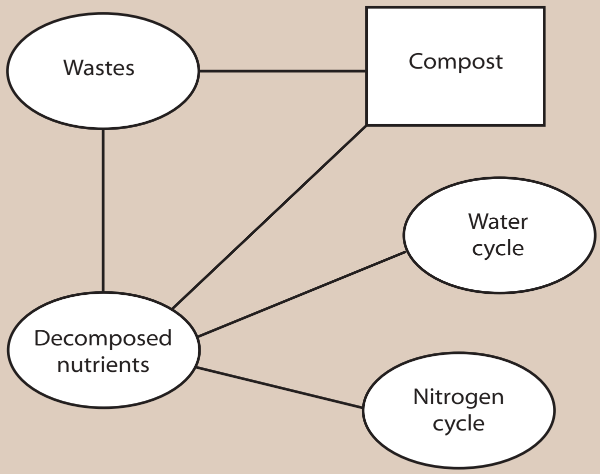
FIGURE 3

Rubric for evaluating concept map.

Criteria	Absent					Excellent
♦ Title of inquiry shown on concept map	0	1	2	3	4	5
♦ At least 25 blocks shown on one or more concept maps	0	3	6	9	12	15
♦ Evidence from inquiry listed	0	4	8	12	16	20
♦ Links between hypothesis and evidence shown on map(s)	0	4	8	12	16	20
♦ Possible new research questions shown on map(s)	0	4	8	12	16	20
♦ Map(s) done accurately	0	3	6	9	12	15
♦ Map(s) drawn neatly	0	1	2	3	4	5
Maximum score = 100 points					Your score = ________	

FIGURE 4

Student concept map.



the students' part concerning how they will be graded.

No rubric is completely objective. Some teachers are reticent to list miniscule details on rubrics for fear of hampering student creativity and originality. They can use less-detailed rubrics called five-point scales. Rubrics with more detailed descriptions of performance expectations are open to less subjectivity of interpretation. Teachers may involve students in constructing a rubric for evaluating their inquiry products. Figures 1, 2, and 3 show sample scoring instruments for inquiry-based activities.

Figures 4 and 5 show reproductions of concept maps produced by a single student during a guided inquiry activity on earthworm composting systems (for details on vermicomposting, see Appelhof 1997). One goal of the activity was for students to link their laboratory observations with biogeochemical cycles studied in class.

The student's first map (Figure 4) was evaluated using the type of rubric shown in Figure 3. The student failed to list a title on the map and therefore earned no points for this criterion. Only five blocks were shown, so the student received three points. The next three criteria are represented sparsely, if at all. The student did link her observation that compost is derived from waste materials and contains "decomposed nutrients." Twelve points were assigned for that link. The map, although simplistic, was accurate (15 points) and neatly drawn (5 points).

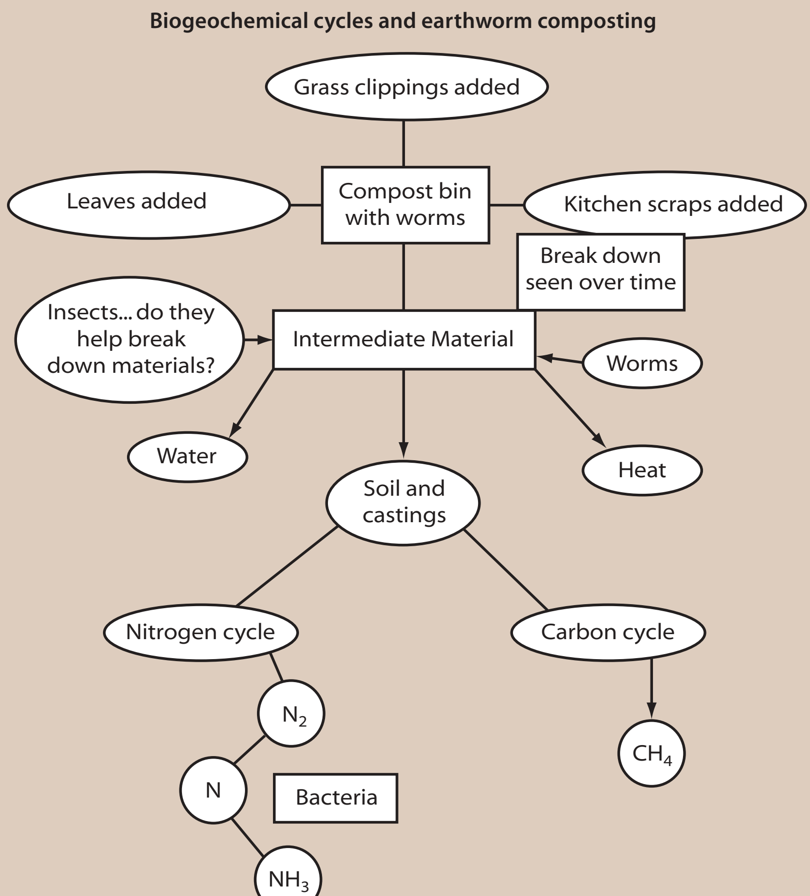
The student revised her map (Figure 5) after discussing her work with the teacher and peers. She also continued her guided inquiry and observations. The second map was also evaluated. The title was shown (5 points). The new map was much more extensive, with 18 blocks shown (12 points). The student included details from her procedure and evidence on the map by indicating that she added grass clippings, kitchen scraps, and leaves to a compost bin and that intermediate material and soil/castings were the result (20 points each). She listed a potential new inquiry question on the map by asking if insects helped to break down raw materials in the compost bin (20 points). The map was accurate and listed some details linking the water, nitrogen, and carbon cycles to the inquiry. More details could have raised the score on this criterion (13 points). Finally, the map was neatly prepared (5 points).

Step Three

Decide who will assign the grade. Teachers traditionally assume full responsibility for grading. Many are comfortable with this method, but others may want to explore alternatives. Some teachers may wish to share the responsibility of grading inquiry with others. A couple of possibilities are listed below.

FIGURE 5

Revised concept map.



Expert judging. Collins (1992) reminds us that experts may be called on to evaluate students. Judging may remind us of science fairs from high school or of essay contests from elementary school. However, we should remember that expert judging takes place at even the highest levels of academia as graduate students present theses or dissertations to a panel of experts for evaluation. Even professional research papers are reviewed by experts before publication. Experts may be given a checklist or rubric to guide their work. Experts may include other teachers, professional scientists, or other professionals in a field relating to a student inquiry project.

Self-evaluation and peer evaluation. Based on our teaching experiences in high school and college classes, we believe that involving students in the evaluation process gives them a deep level of ownership and heightens their interest in the task being evaluated. Teachers may have students grade their own work and/or the work of their peers. Self- and peer evaluation could account for any percentage of the total grade assigned for inquiry-based activities.

Conclusion

The construction and use of scoring rubrics is easily within the reach of science teachers and their students. Teachers who want to use rubrics to grade inquiry activities need only consider their outcome goals, performance criteria, and weight and to determine who will be responsible for assessing students' inquiry-generated work. A good rubric helps both students and teachers evaluate inquiry, its components, and its products. Science teachers are encouraged to use these tools, adapt them to their own needs and circumstances, design other methods, and share them with their colleagues. ■

References

American Association for the Advancement of Science (AAAS). 1990. *Science for All Americans*. New York: Oxford University Press.

Appelhof, M. 1997. *Worms Eat My Garbage*. Kalamazoo, Mich.: Flower Press.

Audet, R.H., P. Hickman, and G. Dobrynina. 1996. Learning logs: A classroom practice for enhancing scientific sense making. *Journal of Research in Science Teaching* 33(2):205–222.

Collins, A. 1992. Portfolios for science education: Issues in purpose, structure and authenticity. *Science Education* 76(4):451–463.

Doran, R.L., L. Boorman, F. Chan, and N. Hejaily. 1993. Authentic assessment: An instrument for consistency. *The Science Teacher* 60(6):37–41.

Enger, S.K., and R.E. Yager, eds. 1998. *The Iowa Assessment Handbook*. Iowa City: University of Iowa.

Foster, S. 1998. New perspective—new practice: Curriculum as a web of inquiry. *Principled Practice in Mathematics and Science Education* 2(1):1–10.

Germann, P.J., and R.J. Aram. 1996. Student performances on the science processes of recording data, drawing conclusions, and providing evidence. *Journal of Research in Science Teaching* 33(7):773–798.

Harker, A.R. 1999. Full application of the scientific method in an undergraduate teaching laboratory: A reality-based approach to experiential student-directed instruction. *Journal of College Science Teaching* 29(2):97–100.

Henderson, L., and C. Buising. 2001. A research-based molecular biology laboratory: Turning novice researchers into practicing scientists. *Journal of College Science Teaching* 30(5):97–100.

Hurd, P.D. 1998. Scientific literacy: New minds for a changing world. *Science Education* 82(3):407–416.

LeBuffe, J.R. 1993. Performance assessment. *The Science Teacher* 67(5):46–48.

Lunsford, B.E. 2002/2003. Inquiry and inscription as keys to authentic science instruction and assessment for preservice secondary science teachers. (Doctoral dissertation, University of Tennessee, 2002). *Dissertation Abstracts International* 63(12):4267.

National Research Council (NRC). 2001a. *Classroom Assessment and the National Science Education Standards: A Guide for Teaching and Learning*. Washington, D.C.: National Academy Press.

NRC. 2001b. *What Students Know: The Science and Design of Educational Assessment*. Washington, D.C.: National Academy Press.

National Science Teachers Association (NSTA). 1996. *Pathways to the Science Standards*. Arlington, Va.: NSTA.

Pearce, C.R. 1999. *Nurturing Inquiry: Real Science for the Elementary Classroom*. Portsmouth, N.H.: Heinemann.

Quinn, H.J., J.J. Mintzes, and R.A. Laws. 2003. Successive concept mapping: Assessing understanding in college science classes. *Journal of College Science Teaching* 33(3):12–16.

Ritchie, S.M., and D.L. Rigano. 1996. Laboratory apprenticeship through a student research project. *Journal of Research in Science Teaching* 33(7):799–815.

Roth, W.-M. 1995. *Authentic School Science: Knowing and Learning in Open-Inquiry Science Laboratories*. Boston: Kluwer Academic Publishers.

Ruiz-Primo, M.A., and R.J. Shavelson. 1996. Problems and issues in the use of concept maps in science assessment. *Journal of Research in Science Teaching* 33(6):569–600.

Shepardson, D.P., and S.J. Britsch. 2001. The role of children's journals in elementary school science activities. *Journal of Research in Science Teaching* 38(1):43–69.

Slater, T.F., J.M. Ryan, and S.L. Samson. 1997. Impact and dynamics of portfolio assessment and traditional assessment in a college physics course. *Journal of Research in Science Teaching* 34(3):225–271.

Zachos, P., T.L. Hick, W.E.J. Doane., and C. Sargent. 2000. Setting theoretical and empirical foundations for assessing scientific inquiry and discovery in educational programs. *Journal of Research in Science Teaching* 37(9):938–962.