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A BACKWARD APPROACH TO INQUIRY

by Sher Hendrickson

The No Child Left Behind Act (NCLB 2001) outlines major reform for elementary and secondary education, putting particular emphasis on alignment of instructional materials and academic assessments with state academic standards (Sec. 1001, PL 107–110). In the sciences, the National Science Education Standards further emphasize that learning science is an inquiry-based process; therefore, teaching methods should be inquiry-based (NRC 1996). In inquiry-based learning, students acquire knowledge by either seeking answers to their own questions or questions posed by the teacher through student-directed investigations. Because of the more open-ended nature of these activities compared to traditional science lessons, implementing Standards-based inquiry activities concordant with NCLB poses a major challenge—how do we assure that academic standards are met during student-centered, inquiry-based investigations?

As part of a collaboration between the Kindergarten-Through-Infinity Systemic Initiative (KTI) program at the University of Wisconsin and the Madison Metropolitan School District (MMSD), I worked closely with teachers in three middle schools, learning coordinators, other graduate students, and teachers attending professional development workshops to examine this question during a districtwide endeavor to integrate Standards-based inquiry into science classrooms.

To confront some of the challenges faced by teachers beginning to implement Standards-based inquiry activities in their middle school classrooms, learning coordinators and teachers selected an inquiry-based set of courses and created a District Science Curricula Scope and Sequence, which overviewed the major units and showed teachers and parents where the curriculum provides opportunities for students to learn the *Wisconsin Model Academic Standards* (State of Wisconsin Department of Public Instruction 1998) by the end of eighth grade. In addition, many schools were in the early stages of establishing their own unique inquiry-based case studies; and these projects needed to be assimilated into the curriculum such that they also met district learning goals. Therefore, not only did we undergo the chaos associated with any new curriculum, but for many teachers, the inquiry-based approach was a recent paradigm shift in science teaching. We used an approach called *backwards design* to help teachers facilitate Standards-based inquiry in their classrooms more effectively.

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Use of a backwards design approach in teaching Standards

Backwards design says that design of curriculum and learning experiences should be "a means to an end" (Wiggins and McTighe 1998, p. 13); we begin by identifying specific learning objectives—in our case the Standards—then all activities, teaching methods, and assessments that support these goals.

Backwards design is not only a way to assure that the curriculum achieves our learning goals by the end of each grade level; it is also a way to approach daily class activities, classroom discussions, and assessment of student understanding. With this approach, instead of moving linearly through a series of labs and activities, conscious effort is made to emphasize particular skills and knowledge needed to meet specific learning goals, and throughout, teachers monitor student understanding and revise their lesson plan accordingly.

We introduced teachers to the concept of backwards design through professional development courses. Not all teachers had participated in the design of the curriculum; however the District Science Curricula Scope and Sequence helped all teachers become familiar with the Standards and provided a basic framework of where the learning objectives should be met. Using the idea of backwards design, we worked together to create more detailed alignments of Standards to daily activities and assessments. This exercise helped us evaluate activities and emphasize learning objectives. Without purposeful guidance, it is easy for student-directed experiments to stray from learning objectives. Having a detailed correlation of the academic standards to each activity, reading, and assessment enabled teachers to guide investigations so that they incorporated learning goals more effectively. Further, student experiments and activities might focus on a single situation or organism, and through leading questions and discussion prompts, teachers were able to help students make the connection between the focused activities and a broader concept.

An alignment between one of our case studies, a bird feeder project, and the Life and Environmental Science Standards we cover in sixth grade is shown in Figure 2. A reference such as this enables teachers to quickly review their main objectives for each day, and also shows where ideas were repeated or "spiraled" throughout the course, so teachers could reinforce a concept by reminding students where they had come across it before.

Clear alignment of course and learning objectives was important for other reasons as well. Classes differed, and some teachers found they had difficulty fitting all the planned activities into instruction time. By knowing the many opportunities students had to learn a particular Standard during a course, each teacher could more effectively revise their lesson plan. Also, in classes where some students' reading abilities were low, teachers could identify activities other than readings that would develop a concept. Further, teachers in many schools have designed their own independent ongoing, inquiry-based case studies, such as our bird feeder case study shown in Figure 2. Thus, we needed an effective way to assure that independent projects fit into the district curriculum and goals.

Methods of assessment

The second important factor for effective Standards-based inquiry is the use of appropriate assessments. Backwards design stresses that assessment is imperative to monitoring student understanding and avoiding misconceptions (Wiggins and McTighe 1998). This does not simply refer to traditional post-activity assignments and tests, but to informal or formative assessments that are given throughout the course so teachers can modify activities to reinforce a weak understanding or rectify a misunderstanding. Formative assessments should allow a student to show growth in understanding without penalization for an early lack of knowledge; therefore they are typically not graded. Further, some science standards are based on skill, such as how to conduct an experiment or construct an explanation for experimental results; and informal methods may be designed to evaluate student proficiency that would otherwise go untested with conventional written exams. Examples of formative assessment methods include:

- teacher observation of performance tasks,
- teacher-student discussions,
- worksheets during the lab activities,
- worksheets covering reading and lab materials, and
- student journals.

What types of assessment are typically being used by teachers?

With our new curriculum and pedagogy, we had just begun to think about how to incorporate informal formative assessment into our inquiry-based activities as a check for student understanding of the Standards. Although we all agreed that monitoring understanding throughout the learning process is important, many find difficulty integrating informal formative assessments into lesson time and traditionally grade-centered classrooms.

FIGURE 1 **Problems and solutions for bringing formative assessment into classrooms during inquiry-based learning activities.**

Issue	Solution
Limited classroom time	1. After teaching a course once (or twice), this may improve. 2. Spread assessment over a few days, most concepts or tasks are not covered in a single day. 3. Make a habit of carrying a record sheet during class and writing informal notes to remind you of good questions, student enthusiasm, understanding, etc. 4. Give some formative assessments as homework.
Limited grading time	1. Giving a simple +/-/√ grade is faster than a letter grade and more appropriate for formative assessments anyway.
Discomfort with not assigning a letter grade to formative assignments; summative and final exams only graded activities	1. If student does poorly on written assessments, but has good grades on other types of assessment, you have a written record of disparity, and can justify a grade change. 2. Use a point system that accommodates growth, i.e., progressively increase the "content point value" as investigation proceeds. 3. Use some formative assessments to model expectations for summative exams. 4. Give students a rubric of expectations for summative exams.
Formative assessments need to be approached consistently by all schools and teachers	1. Create a district rubric for formative assessments. 2. Accommodate formative assessment on report cards.

FIGURE 2 **Sample alignment of activities in our bird feeder case study and Wisconsin Model Academic Standards F. Life & Environmental Science and C. Science Inquiry.**	F.8.1 Understand the structure and function of cells, organs, tissues, organ systems, and whole organisms.	F.8.2 Show how organisms have adapted structures to match their functions, providing means of encouraging individual and group survival within specific environments.	F.8.6 Understand that an organism is regulated both internally and externally.	F.8.7 Understand that an organism's behavior evolves through adaptation to its environment.	F.8.8 Show through investigations how organisms both depend on and contribute to the balance or imbalance of populations and/or ecosystems, which in turn contribute to the total system of life on the planet.	F.8.9 Explain how some of the changes on the Earth are contributing to changes in the balance of life and affecting the survival or population growth of certain species.	F.8.10 Project how current trends in human resource use and population growth will influence the natural environment, and show how current policies affect those trends.	C.8.1 Identify questions they can investigate using resources and equipment they have available.	C.8.2 Identify data and locate sources of information including their own records to answer the questions being investigated.
Introduce ecology case study. Students discuss wildlife, how we can study nature from our inner-city school. Through students, introduce using bird feeders to study species richness, migration timing, etc.					X	X		X	
Students design study site. Group work. Design feeders, select foods and locations. Think about further research students need to do to formalize their plan (read nutrition information on feed bags, etc.). Assignment: Turn in supply list next day.				X				X	X
In groups, present hypotheses and plan to other students. Make bird feeders. Hang feeders (1–2 days)				X					
Discuss types of data we need to collect (types, number, behavior of birds, which feeder/seed used, weather, etc.). Make bird journals.								X	X
Ongoing. Data collection. (10 minutes at class).									
Ongoing. Teacher observation: Does student notice different species of birds choose different types of feeders?				X					
Feather anatomy lesson. Compare bird feathers used for warmth, soaring flight, comunication, etc. View feathers under microscope.	X	X	X						
Ongoing. Teacher observation: Does each student observe that certain species predominate? What does this indicate?					X	X			
Form and function: Discuss diversity. Bird skins, skeleton, beak differences.	X	X	X	X					
Ongoing. Discuss species accounts every Friday.									
Analyze data. Species, individuals, weather, etc. Assignment: Write lab report.									
Group presentations. Discuss inferences about original hypotheses.									

C.8.3 Design and safely conduct investigations that provide reliable quantitative or qualitative data, as appropriate, to answer their questions.	C.8.4 Use inferences to help decide possible results of their investigations; use observations to check their inferences.	C.8.5 Use accepted scientific knowledge, models, and theories to explain their results and to raise further questions about their investigations.	C.8.6 State what they have learned from investigations, relating their inferences to scientific knowledge and to data they have collected.	C.8.7 Explain their data and conclusions in ways that allow an audience to understand the questions they selected for investigation and the answers they have developed.	C.8.8 Use computer software and other technologies to organize, process, and present their data.	C.8.9 Evaluate, explain, and defend the validity of questions, hypotheses, and conclusions to their investigations.	C.8.10 Discuss the importance of their results and implications of their work with peers, teachers, and other adults.
X							
X							
X							
	X						
	X						
X			X				
	X	X	X	X	X	X	
	X		X	X		X	X

Moving forward with assessments

One of the major difficulties expressed by teachers that prevented their use of informal formative assessment was limited class time. Other factors included not enough time for reading written assessments, lack of habit, and discomfort with *not* giving a letter grade. In Figure 1, I list the main challenges to using formative assessments and solutions proposed by teachers and learning coordinators during a group discussion. For example, to deal with limited class time, we suggest carrying a clipboard with a roster attached to note teacher observations of skills and teacher-student discussions. This would spread the assessment over a number of days. Also, although many teachers were uncomfortable with not grading formative assessments, a simple "–/✓/+" marking system was quicker. If "–/✓/+" was not satisfactory, a weighted point system could accommodate student growth.

Although introduction of a Standards-based inquiry approach in the MMSD classrooms is still a work in progress, our suggestions of using alignment, backwards design, and formative assessment may be helpful for other districts struggling to implement inquiry-based pedagogy. Aligning Standards to inquiry curricula ensures that students are provided with opportunities to learn the Standards. Further adopting a backwards-design approach enables teachers to effectively shape inquiry activities to incorporate learning objectives, while use of formative assessment throughout the inquiry process can help teachers monitor learning and facilitate student understanding of the Standards. In this way, we can give our students the opportunity to explore, and yet still ensure the discovery of learning objectives along the way. ■

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