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REFLECTIV

Developing patterns for thinking about learning in science

Your students successfully completed a lab session, correctly filled in all of the worksheets, and collected the required data. Yet, as a science teacher, you still find yourself wondering—what did my students actually learn? And, can they apply that learning to what is going on in their everyday lives?

The process of critical thinking and knowledge application requires more than rote memorization and the ability to get answers correct on lab reports or multiple-choice tests. Purposeful, guided reflection may be an opportunity to gain insight into what students are thinking and learning in relation to science content. This article describes how to use guided reflective writing in the science classroom to provide a window into students' minds.

Critical and reflective thinking

Critical thinking is used to describe the use of those cognitive skills or strategies that increase the "probability of a desirable outcome…thinking that is purposeful, reasoned, and goal directed—the kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions when the thinker is using skills that are thoughtful and effective for the particular context and type of thinking task" (Halpern 1996, p. 10).

Reflective thinking, on the other hand, is a part of the critical-thinking process that refers specifically to the processes of analyzing and making judgments about what has happened. Dewey (1933) suggests that reflective thinking is an active, persistent, and careful consideration of a belief or supposed form of knowledge, the grounds that support that knowledge, and the further conclusions to which that knowledge leads. Learners are aware of and control their learning by actively participating in reflective thinking—assessing what they know, what they need to know, and how they bridge that gap—during learning situations.

The *National Science Education Standards* state that teachers of science, at all levels, must make decisions "such as when to change the direction of a discussion, how to engage a particular student, [and] when to let a student pursue a particular interest" (NRC 1996, p. 33). Teachers struggle to decide when to guide students toward a specific outcome and when to allow them to set their own goals. Because students think about what they are learning, reflection is a way for students to set their own goals as well as guide their own learning. Figure 1 (p. 48) shows the relevant Standards.

Creating a pattern of reflection

The decision to use reflection in the science classroom is one that requires prior planning and thought. You must first decide on the method of reflection to be used. For example, while working on a project or other long-term activity, students might be asked to record thoughts, observations, feelings, activities, and questions in a journal that is maintained throughout the project period. Projects that require a team approach may use a team journal to ensure interaction within the group. Students can be assigned a paper to write based on their journal or engage in class discussions to encourage critical thinking and reflection about their project. The method or methods selected must be based on the project outcomes defined early in the planning process.

Over the course of a project, there will be many opportunities for reflection by both you and your students. By breaking down the project into distinct periods, it is pos-

sible to plan and design the reflection process (Figure 2, p. 49). Some reflection activities may be very structured, while others may be guided by student questions.

Reflection assignments

Science journal reflections

Gaining insight about what students are thinking and learning during the course of a project allows the teacher to make changes in instruction, correct misconceptions, and further explore complex concepts with which students may be struggling. Adding a reflection element that is ongoing provides immediate feedback to both you and students. One way to gain this feedback is through a tool that may already be used in your classroom—a science journal (or notebook).

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Using science journals simply as logs for students to record procedures, observations, and data does not allow students to do their own thinking or explore the learning process (Klentschy 2005). If journals consist mainly of worksheets for data collection, the goal becomes trying to fill in the blanks rather than practicing inquiry and learning. The addition of reflections in the form of student-generated questions, statements about what has been learned, predictions of outcomes, and comments about successes and failures will help students form meaning from their learning experiences. A separate section of the journal (e.g., the left-hand pages) can be reserved for these reflections.

Students may need encouragement to reflect through the use of guided questions. Bricker (2007) suggests sharing student prompts. Students can consider the following:

- What is something I discovered for the first time?
- What did I find that surprised me?
- What happened reminds me of…
- What am I wondering about now?

Questions and responses generated by students through the prompts can then be used to identify concepts that need clarification, provide direction for additional investigations, and uncover misconceptions.

Small group reports

Aside from science journals, the prompts described by Bricker (2007) can also be used in small group discussions in which students combine their questions and responses with others and report back to the entire group. This allows exploration and clarification of complex ideas and concepts as students talk through their learning experiences. Small group discussions also provide a direct benefit to the instructor in terms of time and efficiency. Students are responsible for gathering individual reflections and combining them in a written or oral report. This method significantly reduces the instructor workload related to paging though numerous journal entries and grading them individually.

Both individual journals and small group discussions assist in "establishing an environment where students are not afraid of getting feedback [and developing] a culture of assessment as information rather than judgment" (Peters 2008, p. 27).

FIGURE 1

National Science Education Standards met (NRC 1996).

- Teaching Standard A: Teachers of science plan an inquiry-based science program for their students (p. 30).
- Teaching Standard B: Teachers of science guide and facilitate learning (p. 32).
- Teaching Standard C: Teachers of science engage in ongoing assessment of their teaching and of student learning (p. 37).

Guided reflection papers

One of the most common methods of reflection used in classrooms is the guided reflection paper. The paper—in which students' writing is guided by a series of questions—can be thought of as a more formal version of a journal entry. Students are asked to consider their learning experiences within the context and framework of their science project. Each student may be asked to reflect on

- how he or she felt the group worked together,
- what the overall goal of the project was,
- a new concept or idea learned,
- how the group made decisions about the steps to follow for successful completion of the project, or
- the one most important thing learned.

Assessing this type of reflective assignment may be based more on the mechanics of writing and quality of thought and effort than on content.

Use of a formal, guided reflection paper is a step toward incorporating thinking about learning in a science course. However, unlike the ongoing science journal tool, this type of assignment is typically used at the completion of a project.

Assessment of reflections

The products of open-ended, inquiry-based, and subjective reflection present a unique assessment challenge for the instructor. Reflective products are designed to provide a window into what students are learning. As Peters states, "Assessment's main function is actually to determine the extent of student learning…" (2008, p. 27). It is important to realize that much of the information being gathered should be used to inform instruction rather than to assign grades. With that caution in mind, you need to decide on two critical elements for using reflection as an assessment tool:

- Determine how the reflective piece will contribute to the assessment process.
- Decide the amount and type of structure or guidance that will be provided to students for the reflection products (e.g., discussions, papers, demonstrations, skits, displays, or models).

The type of reflection method selected guides how—or whether—to assess reflective assignments. For example, an unstructured journal or class discussion in which students are asked to reflect on their feelings, attitudes, or experiences may be best graded for completion in the

form of credit or no credit. To objectively assess reflections, the use of guided questions and structured reflection assignments is required.

The following questions are examples of actual guided-reflection questions used during a class in which students were conducting a science project concerning taking action on environmental issues:

- What have you learned about your environmental issue by "taking action"?
- What impact has participation in the action team project had on your life?
- In the future, if you became concerned about an environmental issue, would you be likely to take action? If so, what kinds of actions would you take?

Reflection questions should relate to the central material being taught. Guided questions should be developed based on what you determine to be the enduring understanding students come away with.

Conclusion

Reflection helps students improve their basic communications skills both orally and in written form. It assists each student in self-examining his or her learning experience and leads to the development of better critical-thinking skills. Students integrate their knowledge through the experience of reflection and begin to build a strong, basic understanding of underlying concepts and theories. The process of discussing and reflecting on learning experiences assists students in exchanging critical ideas and insights about the information being shared. Deliberate and guided reflection leads to expanded learning and understanding. In short, reflection creates meaning. ■

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FIGURE 2

Opportunities for reflection activities during a science project.

Project period	Assessment process and activities
The beginning	Ask students to reflect in their journals about what they already know, believe, or assume related to their project concepts. What do they expect to learn? Give them a question to explore during the project.
Behind the scenes	Observe and listen to students as they work in teams. What challenges are they encountering within their groups? What do they need more information about? What would help them move their project along? Make notes and have a class discussion: Ask students to identify their challenges, questions they need answered, and information they need. Have them write their questions in their journals and find the answers.
Project completion	A guided reflection paper is a commonly used method of assessment, but not the only one. Ask students how they could demonstrate their knowledge or illustrate their experience. It might be through a skit, debate, song, story, picture book of concepts for young children, or a play. Students could be asked to defend a conclusion based on the data collected. All of these can be valuable reflective experiences.
Project facilitation and feedback	This is ongoing. If students are keeping project-long journals, review them on a regular basis. Provide nonjudgmental feedback, write responses, listen well, and ask questions. Appreciate the learning experience your students reveal.

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