Teaching Science Learning

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One of the four guiding principles of the National Science Education Standards is simply "science for all students" (NRC 1996). This principle underscores the belief that all students, regardless of race, gender, or disability, should have the opportunity to learn and understand the essential science content described in the Standards. Because of increasingly widespread inclusion practices and more thorough identification procedures, students with documented learning disabilities (LD) are becoming a larger percentage of the science classroom.

Because many practicing science teachers have little training or experience in identifying and meeting the needs of students with disabilities (Norman, Caseau, and Stefanich 1998), we have outlined basic educational principles that support the unique learning needs of these students. Each principle is accompanied by examples of how a science instructor might put that principle into practice.

The success of LD students

Between 5% and 10% of all K–12 children are identified as having a specific learning disability (Department of Education 2002; Kavale and Forness 1995) and it is anticipated that this number will grow. LD students often struggle with academic challenges in both their general high school curriculum and in their science classes (see sidebar "LD definition," p. 28). Between 36% and 56% of LD students leave high school without a diploma or certificate of completion (Collett-Klingenberg 1998), and LD students score almost one standard deviation lower on science achievement tests than those students without disabilities (Anderman 1998).

Using a biology unit on cell transport as the content anchor, we present six principles and practical examples, which were developed as a follow-up to the *Biology Success!* project (an NSF grant–funded project designed to give introductory high school and college biology instructors ideas, tools, and inspiration for teaching diverse learners). The principles draw from a review of science teaching and special education literature and the authors' combined 20-plus years of experience working at a school designed to meet the needs of students with LD and/or attention deficit disorders. While we assume that the principles presented would stand up to the test of good pedagogy for all high school science students, they have proven to be essential to the success of LD students.

Principle 1: Learning is enhanced when teachers recognize and teach to diverse learning styles and strengths.

Learners have diverse ways of making meaning, constructing knowledge, and expressing understanding; using this perception as a starting point in our science teaching is particularly important for LD students. These students—who show deficits in certain aspects of their learning such as organization, reading, memory, and writing—have benefited when instructors accommodate and teach to a variety of learning styles (Carbo and Hodges 1988).

Teachers interested in reaching the broadest range of students can offer multiple means of representing the content in their classroom and provide students with multiple means of expressing their mastery of that content. This universal design approach to education is strongly advocated by organizations that work to expand learning opportunities for those with disabilities, such as the Center for Applied Special Technology (Dolan and Hall 2001). [**Editor's note:** See "Universal Design in Science Learning" on page 32 of this issue of *The Science Teacher*.]

to Students with Disabilities

Guiding principles and practices for adapting instruction for students with learning disabilities

LD definition.

Because of both the frequent co-occurrence of learning disabilities and attention-deficit/hyperactivity disorder (Brown 2000; Katz 2001; Willcutt 2000), and because of the challenges to accurate diagnoses (Hammill 2001; Kamphaus, Frick, and Lahey 1991), we have chosen for this article to follow the Centers for Disease Control and Prevention's model in their 1998 national survey, and not distinguish between subsets of students based upon specific diagnoses. Although various authors in this article cited may have their own definitions, we consider "learning disability" to encompass the range of learning disorders that interfere with academic achievement and social development (Pastor and Ruben 2005).

Principle-to-practice examples

Although this principle may require more time to implement, the field of science lends itself well to teaching to a diversity of learning styles. Teachers can apply the following approaches.

- Provide instruction that reaches the full spectrum of diverse learners.
  Example: Students can see or perform a demonstration of osmosis (real or computer-based), view and/or construct a diagrammatic depiction of diffusion versus osmosis, read a text-based description of cell transport mechanisms, and enact a role play that shows active transport kinesthetically.
- Provide various means of assessment that capitalizes on students' learning strengths or preferences.
  Example: Students can choose from—or the teacher can alternate among—varied-format tests, graphic organizers, oral interviews, three-dimensional models, written summaries, PowerPoint slide presentations, or posters. The teacher could also have a set order to cycle through.

Principle 2: Content learning is supported by explicit instruction in skills and strategies.

The science curriculum is embedded with an ever-increasing array of thinking, study, and organizational skills that are predictors of future academic success (Everson, Weinstein, and Laitusis 2000; Zimmerman 2002). The demands for planning, prioritizing, time management, and follow-through can be daunting for any student, but overwhelming for LD students (Shmulsky 2003).

Before LD students can show mastery of content, they must first be explicitly taught effective ways to study and organize for their courses (Gersten, Schiller, and Vaughn 2000; Swanson, Haskyn, and Lee 1999; Vail, Crane, and Huntington 1999). McCleery and Tindal's (1999) study found that LD students who were provided with an explicit, rules-based template for understanding the thinking behind scientific methods were able to outperform their peers who did not receive this explicit instructional support.

Principle-to-practice examples

LD students may lack basic study strategies in reading, note taking, developing vocabulary, organizing materials, writing, and other study skills. The following instruction strategies will benefit these students.

- Teach and model reading and study strategies for science textbooks.
  Example: Students complete a partially filled outline or graphic organizer of the main ideas and details of the cell transport reading assignment in their textbook. After several assignments like this, students can generate outlines or graphic organizers based on their text reading.
- Teach effective ways to organize, revise, and review notes.
  Example: After recording lecture notes on the topic of cell transport, students can highlight main ideas in one color and details in another color. In teams, students can compare, contrast, and discuss their highlighting choices.
- Teach the structure of lab report writing by providing models and templates.
  Example: After students complete a lab activity on the topic of cell transport, the teacher can distribute a graphic template that explains the structure of a lab report and a sample lab report that follows this structure.
- If the recall of vocabulary is emphasized, then teach and model vocabulary review techniques.
  Example: Students can create and review vocabulary using flashcards or concept-mapping techniques.
- Teach students to use some form of course planner or calendar that shows assignment due dates in a clear, graphical format.
  Example: Students receive a list of key events and due dates for their cell transport unit and then

copy these into their full academic planner or post them in their science notebook in a prominent location.

- Consider giving students the option of leaving their course materials in the classroom so that the loss of handouts, notes, and so on, is minimized.
- Consider making available, in the classroom or learning support center, emerging assistive technologies such as text-to-speech screen readers, which are designed to assist students with difficulties decoding or attending to written text.

Even with suggestions such as these, LD students may need direct monitoring of their progress in keeping organized and applying effective study skills. Developing ways to unobtrusively check organizational and study skills practices may be essential to their success in science courses.

Principle 3: Learning is facilitated when instruction and assessment are clearly organized.

Although explicit organizational schemes are useful for all students, they are particularly important for LD students who are most successful when provided with high structure (Minskoff and Allsopp 2003). Explicit organization of instruction and assessment can positively affect student planning, prioritizing, and goal-setting, all typical areas of difficulty for LD students (Raskind et al. 1999). Teachers should pay special attention to organizing routines and pacing, which are frequently difficult for LD students (Troia and Graham 2002).

Principle-to-practice examples

The following suggestions are ways to emphasize clear and explicit organization.

- Post and review daily agendas for all class activities and assignments.
  Example: During the first class of the cell transport unit, the teacher can post a list of the tasks and their goals. The teacher can then preview the list at the beginning of the class and check off items as they are completed during the class.
- Establish and rationalize a routine for how class operates.
  Example: The teacher can use the posted agenda to create routines that include agenda preview, warm-ups/review, main lesson, application, bookkeeping, and so on.
- Distribute all important assignment handouts in the same format and structure.
  Example: The teacher can create a "homework" template and use it for all assignments in the cell transport unit, using consistently colored paper and headers to "cue" students.

Principle 4: Learning is maximized when instruction and assessment are based on explicit objectives.

In their *Guide to Teaching Science to Students with Special Needs in the Inclusive Setting,* Mastropieri and Scruggs (1993) emphasize clearly stated objectives as a hallmark of effective instruction for LD students. Certainly, understanding the purpose of a lesson or an assessment will enhance the learning of any student, but this understanding is particularly salient for LD students, whose memory capabilities are likely to be compromised as a part of their diagnosis (Hulme and Mackenzie 1992). Clearly articulated objectives, which are easily available and frequently referred to, can be an important reference point, allowing LD students to access and re-access information that is likely to provide both clarification and motivation.

Principle-to-practice examples

The following points provide strategies for making learning objectives explicit during instruction and assessment.

- Make a direct connection, orally and in writing, between each class task and its associated learning objective.
  Example: When facilitating a role-playing demonstration of active transport, the teacher must make explicit at the outset the purpose of the demonstration and provide an opportunity at the end for students to articulate the main idea of the demonstration.
- Provide scoring rubrics that describe the qualities of excellent work for the various components of each assignment.
  Example: If assigning a lab report on some aspect of cell transport from an inquiry-based investigation, the teacher can give students a rubric that describes the qualities of an excellent, adequate, partial, or poor hypotheses statement. Each component of the assignment (e.g., data table, graph) would include similar descriptors of quality.
- Provide (or assign) some form of study guide for students to review before any quiz or exam.
  Example: The instructor can generate a study guide for early units in the course and eventually assign it to students.

Principle 5: Learning is improved when teachers provide consistent feedback.

Using formative evaluations to measure student understanding provides useful "diagnostic" information to teachers, but these assessments are underused unless they are also supplied to students in the form of consistent feedback. Students in general voice a strong preference for frequent and specific feedback (Belcheir 1998), and this type of feedback is important to realistic self-assessment and ultimate success (Linnenbrink and Pintrich 2002; Pintrich 2002).

In addition to providing important self-assessment information, frequent feedback enhances motivation, which is important to academic achievement (Linnenbrink and Pintrich 2002; Pintrich and Schunk 2002). The benefits of feedback, while important to all students, are essential to LD students who have a tendency to falsely estimate their academic abilities (Heath and Glen 2005) and whose diagnoses and academic histories can make sustained motivation difficult.

Principle-to-practice examples

Some ways to offer consistent and helpful feedback for students in science exist.

- Instead of relying on large unit tests or exams, build in more frequent forms of assessment.
  Example: A teacher can design a quiz that assesses learning about cell transport only, as opposed to folding it into a larger unit test on cells.
- Use grade-keeping software and make updated grade reports accessible to students.
  Example: A teacher can regularly distribute individual grade reports that include recent quizzes, reports, or other assignments and any missing work, and connect these assignments explicitly to their overall course grade.
- Provide direct personalized feedback to students.
  Example: Where possible, a teacher can give direct and positive verbal feedback to students at the "point of performance" in the classroom.

Principle 6: Learning is sustained when students develop self-knowledge.

Although self-awareness is not sufficient to yield success, it can create the readiness to transform abilities into success-producing, academic skills (Pintrich 2002; Pintrich and Schunk 2002; Zimmerman 2002). Accurate self-knowledge is particularly important to students whose learning styles do not match those of typical learners. Not only does understanding one's disability remove some of the stigma and self-blame associated with a learning difficulty, but also it is a prerequisite to being able to apply successful, personalized learning strategies.

By increasing their own understanding of learning styles and disabilities, science teachers can help impart this information to their students, thus increasing students' metacognition and their ability to begin advocating for themselves as learners.

Principle-to-practice examples

Some ways science teachers can build in metacognitive learning for their students follow.

- At the beginning of a course, have a conversation about the value of understanding one's learning profile and/or let students take a learning style survey.
- Explicitly share with students your observations about their learning strengths and challenges as the course progresses.
- Build metacognitive reflection into assignments.
  Example: At the end of an assignment or unit on cell transport, students can assess their learning strategies. Teachers can reference this assessment at the start of the next unit or assignment.

Realizing the vision

For students whose diagnosis makes sustained motivation difficult and academic failures all too commonplace (Dunwoody and Frank 1995; Gunther-Mohr 2003), maintaining an internal belief in personal capabilities can be very difficult. If teachers can help students foster a positive attitude, they are likely to enhance the educational experience for students in general (Martin, Swartz-Kulstad, and Madison 1999; Zimmerman 2002) and LD students in particular (Wallace, Winsler, and Nesmith 1999). By applying the principles and practices described here, science teachers can better serve the personal and academic needs of LD students and thus help realize the vision of the National Science Education Standards guiding principle "science for all" (NRC 1996). ■

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