(Dis)Solving the Differences: A Physical Science Lesson Using Universal Design

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Abstract:
Universal design for learning (UDL) holds promise for teachers who are struggling with creating lessons that allow all students access to and engagement with the general science curriculum. In this article, the authors demonstrate how a secondary physical science lesson about solubility and concentration can be designed for diverse learners' needs by implementing UDL concepts. The lesson plan serves as an example of UDL in providing appropriate instruction that supports access to the general physical science curriculum for all learners.
Keywords: accommodations; instruction; science

Article:

Today's rigorous, content-oriented science classrooms can be daunting for students with physical, cognitive, or affective challenges, and for the teachers who teach them. Students with learning disabilities (LD) may need instructional accommodations to assist them in grasping the big ideas presented in class. Students with reading disabilities might have underlying language difficulties that make comprehension of science concepts and terms overwhelming. A slow reading rate and an inability to comprehend expository writing can make grasping science content difficult for students with disabilities.

In science classrooms throughout the country, providing these educational accommodations requires teachers to design instruction that ensures access to and success with the classroom curriculum for all their students. Science may be one of the most valuable subjects that can be taught to students with disabilities (Mastropieri, Scruggs, & Magnusen, 1999; Scruggs, Mastropieri, & Boon, 1998). Researchers have suggested that instructional activities in science that have elements such as concrete, hands-on, inquiry-based learning activities and group interaction can create high interest among students (Mastropieri, Scruggs, & Graetz, 2005; Scruggs, Mastropieri, Bakken, & Brigham, 1993).

As students with disabilities spend more time in general education classrooms, the ability of general education teachers to include these students in all learning activities becomes even more important (U.S. Department of Education, 2005). Although there is no single model for all students or all disabilities, there are best practices that can be used to teach to the strengths of students with special needs, while also meeting the educational needs of general education students. Many of these practices tend to be inherent in good science teaching in general, but various modifications may be required to maximize their benefit to students with varying levels of experience and ability. The use of universal design for learning (UDL) as one of these instructional approaches may be of particular interest to science teachers and special education teachers as they work together to address the specific learning needs and styles of their students (Center for Applied Special Technology [CAST], 2006; Curry, Cohen, & Lightbody, 2006; Orkwis & McLane, 1998; Rose & Meyer, 2002).

Legislation and Students With LD

Under the influences of current legislation such as No Child Left Behind (NCLB), outcomes for students with diverse educational needs, including students who receive special education services, are influenced by teachers' abilities to clearly depict concepts and big ideas (Council for Exceptional Children, 2007). As such, teachers must offer students multiple opportunities for engagement with learning (Ellis, Farmer, & Newman, 2005; Howard, 2003).

One of the most significant issues of NCLB and the Individuals with Disabilities Education Improvement Act (IDEIA) is the importance of making the general curriculum accessible to all students (Individuals with Disabilities Education Improvement Act, 2004; No Child Left Behind Act, 2001; U.S. Department of Education, 2005). Although neither law specifically directs how schools are to create accessible curricula for all students, the legislation holds teachers, schools, school districts, and state departments of education accountable for ensuring that all students make progress toward the high standards set forth in assessed content areas (CAST, 2006).

Most curricula tend to be rigid, with little flexibility embedded to meet the individualized educational needs of diverse learners (Vaughn, Bos, & Schumm, 2000). Many of the suggested modifications for adapting the curricula for diverse learners, particularly students with disabilities, have been viewed by teachers as add-ons. For example, shortened assignments or remedial instructional activities addressing specific areas of need may be considered ineffective for meeting students' individual learning needs (Rose & Meyer, 2002).

Prior to the move toward more inclusive educational practices and the accountability issues associated with NCLB legislation, high school students with special needs more often than not met with special education resource teachers when content area classes convened. Resource teachers collaborated and planned with general education teachers to meet the needs of students and to support the instruction that was provided in the general education classrooms. NCLB legislation, focused on accountability in meeting educational standards for all students, left many general education teachers fully responsible for the instruction of all students. In the best of circumstances, content area teachers and special education teachers have been able to implement a collaborative teaching model, but this is not always the case (Murawski & Dieker, 2004). Although there are resources available to prepare general education teachers to teach students with special needs in the general curriculum, many teachers are trying to teach students with disabilities but have little or no training or experience to do so (Council for Exceptional Children, 2004).

UDL and Students With LD

Students with LD may struggle with content area instruction. For example, they may have underlying language difficulties that overwhelm acquisition of new concepts and information, or they may lack basic skills in reading, writing, and math (Schloss, Smith, & Schloss, 2001). As teachers plan for content area instruction for students with LD, they must consider the factors that can influence successful learning by these students. Carnine and Carnine (2004) suggested that there are specific instructional design principles that can improve science comprehension, science processes, and higher order thinking. Science teachers should identify and teach big ideas; use systematic instruction of vocabulary; review and integrate core concepts, including visual displays of how core concepts are integrated; use mnemonic strategies for core concepts; and provide structured hands-on activities (Carnine & Carnine, 2004; Chiappetta & Koballa, 2006; Slocum, 2004).

These principles can be applied using UDL, an approach to instruction that is supported by integrating brain-based learning theories, research-based best practices, and instructional technologies, and that offers powerful applications of how learning can most successfully occur for all students (Cawley, Foley, & Miller, 2003; Hitchcock, Meyer, Rose, & Jackson, 2002; Howard, 2003; Pisha & Coyne, 2001; Pisha & Stahl, 2005; Rose & Meyer, 2002). According to CAST, three components of the UDL framework are (a) multiple means of representation (providing content in different modes—visual, graphic, or auditory, for example—so that all students have diverse ways to access information), (b) multiple means of expression (providing students with many opportunities to demonstrate what they have learned), and (c) multiple means of engagement (providing a variety of ways to involve students in learning; Curry et al., 2006; Orkwis & McLane, 1998).

UDL for Secondary Physical Science

A model lesson on solubility from a secondary physical science lesson is offered to demonstrate implementation of UDL components (see Tables 1, 2, 3, 4, and 5). The purpose of this lesson on solubility is to teach students how one substance dissolves in another sub-stance. Using the simple example of making sugar water, one dissolves a certain amount of sugar (called a solute) in a certain amount of water (called the solvent). If too much sugar is added, it falls to the bottom of the glass (i.e., there is a limit as to how much sugar will dissolve in a specific amount of water at a given temperature). If the water temperature is raised, more sugar will dissolve, but if sugar comes out of the solution (precipitates) when the solution cools, then the solution is saturated.

TABLE 1
Universally Designed Lesson Plan Model: Goals

Lesson Components	UDL Instructional Supports	Example: Physical Science Lesson on Solubility
Goals	Aligned with national standards	*National Science Education Standards:* *Content Standard A:* A-1 Abilities necessary to do scientific inquiry A-2 Understandings about scientific inquiry *Content Standard B:* B-2 Structure and properties of matter B-6 Interactions of energy and matter
	Aligned with state and/or district competencies, standards, or frameworks	*Unifying Concepts and Processes—UPC:* Systems, order, and organization Evidence, models, and explanation Change, consistency, and measurement Form and function *North Carolina Standard Course of Study:* 6.04 Measure and analyze indicators of chemical change; investigate and analyze properties and composition of solutions

Note: UDL = universal design for learning.

TABLE 2
Universally Designed Lesson Plan Model: Instructional Objectives

Lesson Components	UDL Instructional Supports	Example: Physical Science Lesson on Solubility
Instructional objectives	Use planning pyramid (Schumm, Vaughn, & Harris, 1997) as its basis	All students will define solubility and list three types of solutions; Most students will identify how to express the concentration of solutions; Some students will describe the effects of pressure and temperature on the solubility of gases.

Note: UDL = universal design for learning.

For a saturated solution, the maximum amount of sugar is dissolved in a given amount of water at a specific temperature. An unsaturated solution means that more solute (sugar) can be dissolved in a given amount of solvent (water). A supersaturated solution can be created by heating the sugar water and dissolving more sugar than would be expected to dissolve in water at the higher temperature.

TABLE 3
Universally Designed Lesson Plan Model: Lesson Description

Lesson Components	UDL Instructional Supports	Example: Physical Science Lesson on Solubility
Lesson description	*Resources* UDL principles	Textbook, handouts, milk carton, bottle of concentrated acid, computers and printer, paper, color pencils or crayons, graph paper, computer, e-handouts (hard copy and digital text), digital photographs, textbook on audiotapes, Web, CD, print. Computer and Internet Web sites: www.dcwasa.com/about/facilities.cfm#wastewatertreatmemt www.graphicorganizers.com http://nc.gpscience.com/self_check_quiz http://nsdl.org
	Strategies Differentiating instruction	Compacting or chunking of important key information throughout lesson Questions for varied ability levels Flexible grouping arrangements K-W-L chart and other graphic organizers

Note: UDL = universal design for learning.

Because sugar molecules are large (unlike salt) it takes longer for them to precipitate or crystallize. Students can suspend a string from a pencil laid over the top of a glass into a supersaturated sugar water solution and sugar crystals will slowly start to form on the string, making students a sweet treat (i.e., rock candy) and reinforcing the concepts of solubility.

All supersaturated solutions are unstable. Super-saturated solutions can be pushed toward the saturation equilibrium by agitating the solution, scratching the beaker, or seeding the solution with a crystal of the solute. For example, carbonated water is a supersaturated solution of carbon dioxide gas in water. At the elevated pressure in the bottle, carbon dioxide can dissolve in water more than at atmospheric pressure. At atmospheric pressure, the carbon dioxide gas escapes from the supersaturated liquid, thus the bubbles seen rising slowly from the bottom of a glass.

TABLE 4
Universally Designed Lesson Plan Model: Instructional Sequence

Lesson Components	UDL Instructional Supports	Example: Physical Science Lesson on Solubility
Instructional sequence using UDL	*Representation:* Includes various ways content will be presented in different ways to meet the needs of all students.	*Representation: teacher* Lecture notes: by lecture, print, and audiotape; teaching vocabulary and major concepts. Science journal: students will imagine they have a crystal and a solution of zinc chloride. They will explain how to use the crystal to tell whether the solution is saturated, unsaturated, or supersaturated. Demonstration: open can of soda. Point out that when soda is sealed, pressure keeps the gas in solution. Once opened, pressure is reduced bubbles become visible. Explicit instruction: On the board draw three identical large beakers. Draw the same number of small circles in each beaker (representing particles of solute). Ask students to copy drawings and color in circles to represent saturated, unsaturated, or supersaturated solutions. Assessment: journal entry, open-ended questions.
	Expression: Includes various methods students will use to demonstrate what they have learned. Activity giving students opportunity to attain intended learning outcomes.	*Expression:* student Oral: Vocabulary (matching definitions game) Talking word processor for definitions Online atlas for definitions of terms K-W-L chart created Written: E-text vocabulary handout/written handout Electronic virtual lab Completed worksheet printed or handwritten worksheet Highlighting feature of word processing program Artistic: Create multimedia product using online resources
	Engagement: Includes various pathways in which students will learn the concepts presented. Pacing to sustain interest and facilitate learning. A balance between teacher-directed and student-centered activity.	*Engagement: teacher/student/curriculum* Partner activity to plot a solubility curve graph from data on e-worksheet using multicolors and/or plot graph Excel spreadsheet. Virtual investigations: virtual lab-solution chemistry. Foldables: solubility and concentration. Web site activities: Online, search for wastewater facility and find out what is dissolved in the water. Create a graph that shows solutes and their quantities in water. Virtual investigations rubric, foldables rubric, task analysis, self-check form, open-ended questions, computer print-out worksheet.

Note: ***UDL = universal design for learning***

TABLE 5
Universally Designed Lesson Plan Model: Assess Learning Outcomes

Lesson Components	UDL Instructional Supports	Example: Physical Science Lesson on Solubility
Assess learning outcomes	How teacher and students will assess what has been learned	Construct a graph of the amount and types of contaminants released in the effluent at a wastewater facility Create a final product that demonstrates understanding of scientific terms Self-assessment: textbook quiz or http://nc.gpscience.com/self_check_quiz Review of journal entries: Check for understanding in whole class discussion Creation of foldable

Note: UDL = universal design for learning.

Another important solubility concept is that of concentration of solutions. The concentration of a solution refers to the quantity of a solute in a given quantity of solvent. A diluted sugar water solution is only faintly sweet, whereas a concentrated sugar water solution is sickeningly sweet. Molar concentration (i.e., moles per solute per liter of solution) is most often used to describe the concentrations of solutions (Hill & Petrucci, 1996). An environmental application of solubility concepts involves the investigation of various substances that are dissolved in water that is released from wastewater treatment plants. Because wastewater treatment plants release water with a certain number and amount of substances, it is important that these substances are monitored carefully, because one person's wastewater upstream is another per-son's drinking water downstream.

Tying It All to UDL

The implementation of the three components of the framework for UDL to generate this physical science lesson on solubility includes several examples of UDL. Multiple means of representation can be created by adapting explicit instruction through the use of the highlighting feature of a word processing program, which can be a visual cueing system to help identify key scientific concepts, big ideas, and vocabulary. Students could benefit from an alternative means of expressing what they have learned in lab activities by using a virtual laboratory in which they use the computer to complete experiments (National Science Digital Library, 2007). An instructional plan could be developed that includes behavioral goals supporting student choice making through multimedia science class projects and assignments using the Internet as an alternative to the science textbook, which could help move students toward engagement, empowerment, and self-control. Through these components, students with diverse educational needs are provided access to the general curriculum through differentiated methods and materials of instruction.

UDL, the Planning Pyramid, and Science Instruction

Instruction using UDL for diverse learners might be tailored around the planning pyramid created by Schumm, Vaughn, and Harris (1997). In this approach to planning, teachers create instructional goals within lessons that (a) all students will learn (the bottom of the pyramid), (b) most students will learn (the middle of the pyramid), and (c) some students will learn (the top of the pyramid). Although not part of an experimental study, the secondary physical science class that was exposed to instruction using Schumm et al.'s learning pyramid in conjunction with UDL experienced improved student performance on the state assessment of physical science (Smallwood & Kurtts, 2006). Combining these approaches assists the teacher in teaching background knowledge, while also using the strengths students bring to the learning situation. Once the goal is achieved, the pyramid is literally upside down, with most of the students at the top (see Figure 1). Lessons allowing for differentiation of instruction can include the components of UDL as with the model lesson on solubility. This lesson addresses the National Science Education Standards (National Science Teachers Association, 1996) and the physical science standards from the North Carolina Standard Course of Study (2006), which are based on the national standards (see Table 6).

Opportunities for engagement with the lesson for all students are created through partner work in plotting a solubility curve graph using an Excel spreadsheet and creating a *foldable* with a rubric on solubility and concentration (Zike, 2002). Foldables (made by folding, cutting, and pasting paper) are creative three-dimensional student-made educational manipulatives, or graphic organizers, that quickly allow students to display and arrange information, making it easier for them to grasp concepts, theories, processes, facts, and ideas or to sequence events (see Figure 2). Foldables can provide a sense of student engagement with the curriculum. Teachers may find a rubric (see Table 7) helpful in their assessment of students' foldables on solubility and concentration.

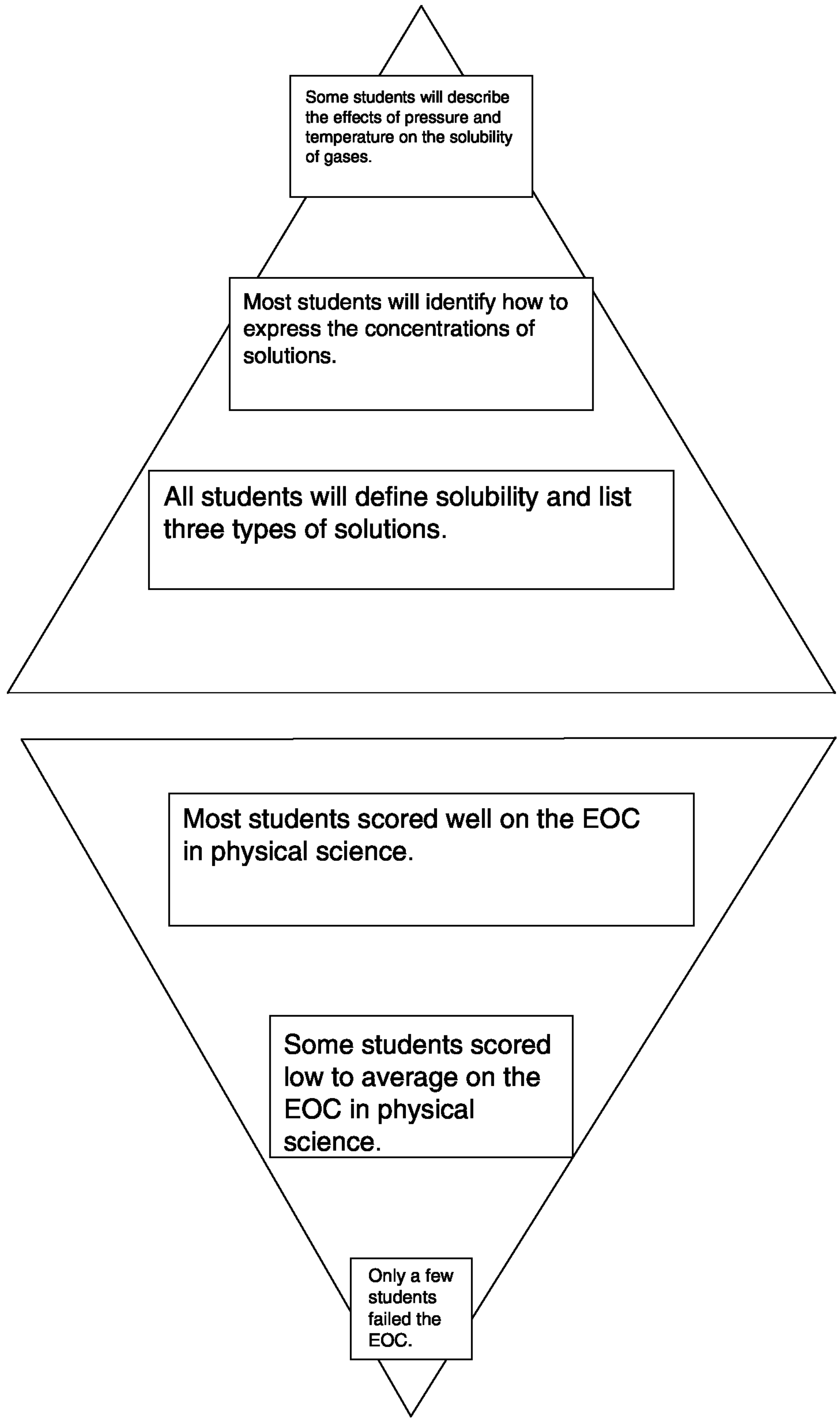

Figure 1. The Planning Pyramid

TABLE 6
Science Standards

National Science Standards	North Carolina Standard Course of Study
Content Standard A: A-1 Abilities necessary to do scientific inquiry A-2 Understandings about scientific inquiry *Content Standard B:* B-2 Structure and properties of matter B-6 Interactions of energy and matter *Unifying Concepts and Processes-UPC:* Systems, order, and organization Evidence, models, and explanation Change, consistency, and measurement Form and function	The learner will build an understanding of generalities in chemistry. 6.04 Measure and analyze the indicators of chemical change 6.05 Investigate and analyze the properties and composition of solutions: Solubility curve Concentration Polarity pH scale Electrical conductivity

Source: National Science Teachers Association (1996); North Carolina Standard Course of Study (2006).

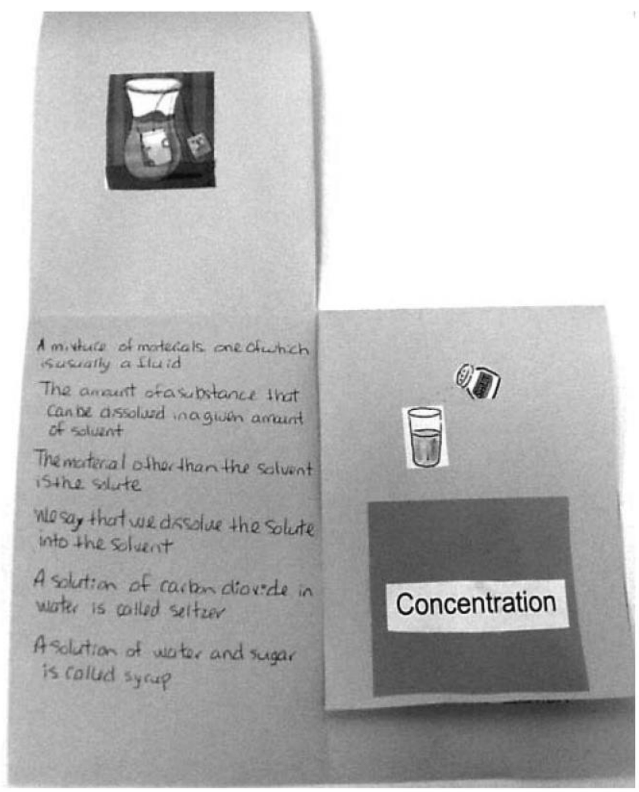

Figure 2. Example of a Foldable

TABLE 7
Sample Rubric for a Foldable

Student Name: ____________________ **Topic/Subject:** ____________________

Component	*Target* = 4	*Acceptable* = 3	*Needs Improvement* = 2	*Not Acceptable* = 1	Score
Creativity and organization	The foldable is highly creative and information is very well organized.	The foldable is creative and information is organized.	The foldable is somewhat creative and information is somewhat organized.	The foldable is not creative and information is not organized.	
Amount of information	All concepts within this topic are thoroughly addressed; there is an extensive amount of information on the topic.	All concepts within this topic are addressed; there is adequate information on the topic.	Most concepts within this topic have been addressed; more information is needed on some topics.	Most concepts within this topic are not addressed; there is limited or no information on most topics.	
Quality of information	Thorough information is provided on all main concepts of the topic, supported by full details and the examples.	Adequate information is provided on main concepts of the topic supported with details and at least one example.	Information provided on some concepts of the topic with limited support of the topic.	Information provided does not address main concepts of the topic and does not support the topic.	
Content accuracy	Content is 100% accurate and listed in the appropriate areas.	Content is 90% or more accurate and listed in the appropriate areas.	Content is 80% or more accurate and listed in the appropriate areas.	Content is less than 79% accurate; not listed in the appropriate areas.	
Illustrations/ graphics	Illustrations feature several types of graphics; text or captions included.	Graphics are included; there is some text or captioning.	Too few, too many, or distracting graphics are featured on the foldable; limited or no text or captions.	There are no graphics or graphics featured are not appropriate for the subject.	

TABLE 8
Sample K-W-L Chart: Solubility and Concentration

In This Column, Write What You *Know* About This Topic	In This Column, Write What You *Want* to Know or Things That You Are Curious About	In This Column, Write What You Have *Learned*
Some gases have strong odors; some are odorless Carbonated sodas have bubbles of gas in them that stay even when you open the can Warm water dissolves sugar better than cold water	What is a solution and what are some examples? Why do some sodas bubble over or explode when you open them? What does it mean when orange juice is from concentrate?	Solubility is the maximum amount of a solute that can be dissolved in a given amount of solvent at a given temperature Gases are more soluble in cooler solvents Sodas bubble over because gas bubbles are exposed to the surface and come out of the solution

The creation of a K-W-L chart could also provide opportunities for students to become engaged in the learning process. K-W-L charts are graphic organizers (Ogle, 1986) used to activate students' prior knowledge (what they already *K*now; what they *W*ant to learn; and after the lesson, what they have *L*earned). Table 8 pro-vides a sample K-W-L chart for the solubility lesson. Students apply higher order thinking strategies that help them construct meaning from what they have read, heard, and seen. These instructional tools can help students organize information within a meaningful context. Use of the Internet would combine technology with practical application as students became involved in scientific investigations on contaminants in wastewater effluents. In addition, the Internet could provide a vehicle for assessment activities as students choose to complete online self-check quizzes that support textbook readings at http://www.nc.gpscience.com/self_check_quiz(Glencoe Online Learning Center, 2005). levels by using foundational knowledge based on the planning pyramid and then using that information to create lessons based on the principles of UDL. They can open up new ways of learning for their students that are exciting and engaging, and which may result in improved student academic performance.

Conclusion

The use of ULD appears to be a promising instructional approach to meeting the educational needs of diverse learners. The flexibility of offering multiple opportunities for representation, expression, and engagement for student learning is encouraging for secondary science teachers as they search for the most effective instructional strategies to meet the educational needs of increasingly diverse student populations. Science teachers need to understand how such approaches to instruction can be designed to effectively differentiate instruction to meet students' individualized instructional goals. In diverse and inclusive classrooms, meeting the needs of all the students is hard work. Science teachers may be able to plan for their students' educational needs at all.

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