The Inclusive Classroom

Meeting the Needs of Gifted Students: Differentiating Mathematics and Science Instruction

IT'S JUST GOOD TEACHING

Northwest Regional Educational Laboratory

Preface

IN THE PROCESS OF IMPLEMENTING STANDARDS-BASED reform, it is important to remember that the charge to provide **all** students with challenging mathematics and science requires consideration of high ability students. Today's heterogeneous classrooms will include students who have advanced abilities and talents. It is essential that the needs of these gifted students not be overlooked or neglected as teachers strive to help others reach high standards.

Meeting the Needs of Gifted Students: Differentiating Mathematics and Science Instruction offers teachers a variety of strategies and resources for providing different levels of content and activities that will challenge all students, including gifted learners. A consistent theme throughout this publication is that while many of the ideas come from the body of literature and research on gifted education, the strategies are appropriate and effective for a wide range of students. Another important theme emerging from the research base on gifted students is the need to re-examine the criteria and processes used to designate some students as gifted, and thus by implication all other students as not gifted. Clearly, relying on a narrow definition such as those who score in the top 10 percent on a standardized achievement test can exclude students with special talents who may have difficulty in taking tests.

This publication is part of the Northwest Regional Educational Laboratory's series, It's Just Good Teaching. This series of publications and videos offers teachers research-based instructional strategies with real-life examples from Northwest classrooms. *Meeting the Needs of Gifted Students: Differentiating Mathematics and Science Instruction* is one of a three-issue focus on the diverse needs of students in inclusive classrooms. Two other publications in the series address strategies for teaching students with learning disabilities and students who are English-language learners. We hope readers will find this publication useful in their efforts to provide all students with high-quality mathematics and science learning experiences.

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Northwest Regional Educational Laboratory

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The It's Just Good Teaching series includes publications and videos that illustrate and promote effective teaching strategies. Single copies of the publications are available free of charge to educators within the Northwest Regional Educational Laboratory's region of Alaska, Idaho, Oregon, Montana, and Washington. To request a copy, contact NWREL's Mathematics and Science Education Center, by e-mail at math_and_science@nwrel.org, by telephone at (503) 275-0457, or visit the Center's Web site, www.nwrel.org/msec/. Additional copies, and copies to individuals outside of the region, may be purchased through NWREL's Document Reproduction Service, 101 S.W. Main Street, Suite 500, Portland, Oregon 97204-3297. Direct e-mail orders to products@nwrel.org; fax orders to (503) 275-0458; and telephone inquiries to (503) 275-9519. Online versions of the publications are available in PDF format at the above Web address.

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Scenes from the Classroom

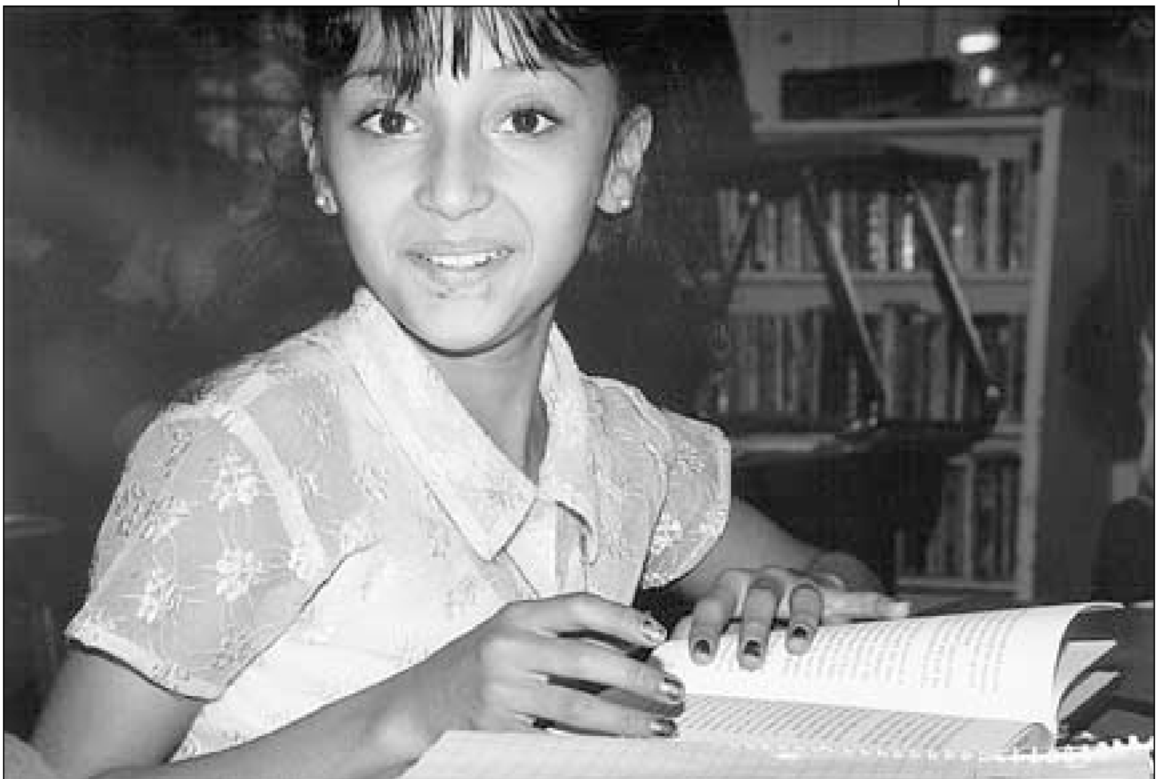
Introduction

THE SCOPE AND PURPOSE OF GIFTED EDUCATION HAVE undergone a number of significant changes over the past two decades. The criteria governing which students are identified and labeled as gifted have evolved according to new theories about the nature of intelligence. Educational reform has also had an impact, as schools strive to raise standards and expectations for all students. Charges of elitism and discrimination have forced gifted specialists and advocates to defend their programs. At the same time, such charges have inspired schools to examine the methods they use to identify gifted students—potentially opening up opportunities to a broader spectrum of students.

> THAT STUDENTS DIFFER MAY BE INCONVENIENT, BUT IT IS INESCAPABLE. ADAPTING TO THE DIVERSITY IS THE INEVITABLE PRICE OF PRODUCTIVITY, HIGH STANDARDS, AND FAIRNESS TO THE STUDENTS.
>
> *Horace's Compromise* (Sizer, 1984)

Is the idea of giftedness truly relevant in an educational climate that emphasizes equity and excellence for all students? When exploring this question, it is essential to remember that although some students learn more quickly than others or are ready to take on more challenging content, those students are not more important or more deserving than others. Recognizing these differences simply means acknowledging that students differ from one another. Expecting gifted students to fend for themselves as the class repeats concepts that they have already mastered is just as unfair as forging ahead while some students are still trying to grasp a concept.

Unfortunately, many educational traditions make it difficult to address student differences. Teachers, students, and parents share an image of what teaching is supposed to look like: The teacher presents the lessons to the whole class and all students complete the same assignments at the same time. Many educators believe that this has seldom been the best way to promote learning. It has become increasingly ineffective as classrooms become more inclusive and diverse. Consequently, strategies for differentiating instruction are an important part of every teacher's repertoire. It is not a matter of giving gifted students more attention or better resources, only of meeting all students' unique learning needs.



Although this publication is primarily concerned with gifted students, the ideas presented here have a much broader application. Most of the strategies are used to create the potential for higher levels of challenge in the classroom. They are not intended to be used exclusively with high-ability groups, advanced classes, or students identified by the school district. In fact, many of the strategies for teaching gifted students mathematics and science will be appropriate for the whole class. This is a theme that resounds continuously in this publication and in much of the literature on teaching gifted students.

Evolving Definitions of Giftedness

IN THE PAST, THE CONCEPT OF GIFTEDNESS WAS ASSOCIATED primarily with high IQ. It was assumed that gifted students were born with high intelligence, were identifiable by their high grades and test scores, and were capable of excelling in all areas of school and of life. These assumptions are still prevalent, although they are beginning to change. Cognitive science, developmental psychology, and new understandings of how learning takes place are influencing the way giftedness is defined and conceptualized. It is clear that there are different ways of being gifted rather than a definitive list of gifted qualities.

Theories of Intelligence

Many of the programs and strategies for teaching gifted students are based on the traditional definition of intelligence. This definition has also influenced the way many people think about education. According to the traditional view, intelligence is a single quality that affects abilities across all domains. It has also been presented as an inherent trait that does not change over time.

> WE ARE NOT ALL THE SAME; WE DO NOT ALL HAVE THE SAME KINDS OF MINDS; EDUCATION WORKS MOST EFFECTIVELY FOR MOST INDIVIDUALS IF THESE DIFFERENCES ... ARE TAKEN INTO ACCOUNT RATHER THAN DENIED OR IGNORED.
>
> "Reflections on Multiple Intelligences" (Gardner, 1995)

Researchers are beginning to challenge the traditional definition of intelligence. Two of the most influential and frequently cited theorists are Robert Sternberg and Howard Gardner. Sternberg has developed the "Triarchic" theory of intelligence, suggesting that there are actually three dimensions to intelligence (Sternberg, 1986). "Compotential" intelligence consists of mental mechanisms for processing information. "Experiential" intelligence involves dealing with new tasks or situations and the ability to use mental processes automatically. "Contextual" intelligence is the ability to adapt to, select, and shape the environment.

Howard Gardner's theory of multiple intelligences is more widely known among educators, possibly because it reflects what teachers know about their students: that there are many different ways of being "smart." Gardner developed his theory by combining studies of the brain with research on the contextual aspects of intelligence. So far, he has identified eight different types of intelligence (Gardner, 1983; 1999): logical-mathematical, linguistic, visual-spatial, body-kinesthetic, musical, interpersonal, intrapersonal, and naturalistic. Schools usually concentrate on the realms of logical-mathematical and linguistic intelligence. Traditional IQ tests and most other standardized tests also measure these two types of intelligence exclusively. However, this may be beginning to change as teachers become interested in Gardner's theory and attempt to weave all eight intelligences into their teaching.

In his book *Outsmarting IQ: The Emerging Science of Learnable Intelligence*, David Perkins synthesizes much of the research and theories of intelligence and groups them into three strands. Neural intelligence is rooted in a biological system and determined by neural efficiency—the brain's physical processes. This is the most traditional view of intelligence. Experiential intelligence involves "know-how" or knowledge of typical patterns or situations. As a result, intelligence is a matter of experience with thinking in particular contexts. Reflective intelligence is based on knowledge of thinking strategies—knowing how to think, how to monitor one's thinking, and how to persist. Perkins suggests that instead of choosing one, all three strands contribute to intelligent behavior (Perkins, 1995).

Joseph S. Renzulli, an educational researcher and director of the National Research Center on the Gifted and Talented, has developed a "three-ring" definition of giftedness, which consists of above-average ability, creativity, and task commitment or motivation (Renzulli, 1998). While a few students will demonstrate these behaviors consistently and across the disciplines, other students may demonstrate them in specific activities or interest areas. Renzulli suggests that the most effective approach to educating

Myths About Gifted Students

There are many misconceptions about gifted students that may prevent schools from providing for their needs. The following are some of the most common myths that are cited as rationale for not providing differentiated opportunities for high-ability students.

Gifted children are smart, so they can get by on their own. When students are not presented with learning experiences that are appropriate for their abilities, they lose motivation and sometimes even their interest in learning and school. Brain research suggests that the brain will not maintain its level of development if students are not challenged (Clark, 1997).

Gifted students excel in all school subjects. While there are students who are high achievers in all areas, many others have subject-specific strengths. Gifted students may struggle in some subjects or activities, while they soar in others. Some gifted students even have learning disabilities (Winner, 1996).

Gifted students are a homogeneous group. Just like any other group, gifted students have different interests, areas of strength, ability levels, and temperaments. There is not a definitive list of gifted characteristics, nor will all students' needs be met with the same strategies. Providing differentiated instruction is a necessity, even in advanced classes (Parke, 1989).

All children are gifted. This is a well-intentioned belief, and it is true that all children can learn and all children have areas of strength. Nevertheless, it is a fact that some students learn more quickly and are capable of a higher level of work than their age peers. Gifted students need different content and instruction in order to meet their needs (Winner, 1996).

high-ability students is for teachers to choose content, instruction, and opportunities according to students' learning needs.

As the concept of intelligence becomes more fluid and multidimensional, the concept of giftedness also evolves. If intelligence is not a single quality, there cannot be a single definition of giftedness. Schools must become more specific about identifying abilities and areas of strength rather than giving students a generic gifted label (Treffinger & Feldhusen, 1996). If intelligence is not static and can be learned, then giftedness can also be developed. There must be an open system for providing curriculum and instruction appropriate to students' needs, rather than a closed system of labeling and self-contained programs.

Identifying Gifted Students

Good grades and high scores on IQ and achievement tests are certainly two indications that a student is gifted. However, there are a number of ways beyond grades and test scores that students demonstrate their abilities and strengths. When schools limit their identification efforts to only these traditional measures, there are many unidentified students whose needs will not be acknowledged or addressed. In addition, there are many high-ability students who do not meet state or district requirements for the label "gifted," but who are capable of exemplary work and who need higher levels of challenge.

One of the most pernicious problems that schools face in identifying gifted students is that African American, Hispanic, and Native American students are underrepresented in gifted programs while white and Asian students are overrepresented (U.S. Department of Education, 1993; Zappia, 1989). In addition, gifted students with limited English proficiency are often overlooked because most tests require oral or written language skills (Cohen, 1990). Ultimately, teachers, school leaders, parents, and students must acknowledge that students from all cultures and backgrounds have the potential to be high ability learners.

Providing instruments and strategies for identifying culturally and linguistically diverse students is beyond the scope of this publication. However, there are a number of materials that focus on these issues. Two of the most thorough resources are *Reducing Disproportionate Representation of Culturally Diverse Students in Special and Gifted Education* (Artiles & Zamora-Durán, 1997) and *Critical Issues in Gifted Education: Defensible Programs for Cultural and Ethnic Minorities* (Maker & Schiever, 1989).

Teachers and schools must use multiple sources of data in order to identify gifted students effectively. In addition to grades and test scores, there are a variety of other forms of assessment that provide a richer and more accurate picture of students' strengths and abilities, such as interviews with students, information from parents, and portfolios of student work (Smutny, Walker, & Meckstroth, 1997).

Teacher observations are often the best source of information for identifying high-ability students. Students who are gifted in mathematics and science may not excel in other school subjects, and therefore may not be formally identified. Even within mathematics and science disciplines, students' abilities may vary depending on the topic or the activity. Therefore, it is important for all teachers to learn about gifted behaviors and characteristics. Also, teachers who establish relationships with their students are able to use that knowledge to guide instruction, rather than relying on a list of gifted students identified by the district or the school. Some indicators of mathematical and scientific giftedness are included in the sidebar on this page.

Indicators of Mathematical Giftedness

- Unusual curiosity about numbers and mathematical information
- Ability to understand and apply ideas quickly
- High ability to see patterns and think abstractly
- Use of flexible and creative strategies and solutions
- Ability to transfer a mathematical concept to an unfamiliar situation
- Use of analytical, deductive, and inductive reasoning
- Persistence in solving difficult and complex problems

(Holton & Gaffney, 1994; Miller, 1990)

Indicators of Scientific Giftedness

- Strong curiosity about objects and environments
- High interest in investigating scientific phenomena
- Tendency to make observations and ask questions
- Ability to make connections between scientific concepts and observed phenomena
- Unusual ability to generate creative and valid explanations
- Interest in collecting, sorting, and classifying objects

(Yager, 1989)

It is also important to remember that high ability students may not fit the traditional mold of a "good student." Relying on observations to identify students requires that teachers become aware of any assumptions or stereotypes they may have about who can be gifted. For example, gifted students may have behavior problems. Some students cause disruptions when they are frustrated or unchallenged. Students may ask a lot of questions or generate off-topic discussions. They may take longer to complete assignments when they add details and extend ideas, or they may race through their work, turning in messy papers with careless mistakes.

Opportunities for challenge and extended learning must be open to all students whenever possible. This is especially true of advanced classes. If a student is interested in taking a high-level class and is willing to put in the extra effort and time required, she should be allowed to demonstrate that she is capable of advanced learning.

Gifted Students and the Inclusive Classroom

Challenge is one of the key components of effective curriculum and instruction. Brain research indicates that learning takes place when students' abilities and interests are stimulated by the appropriate level of challenge (Caine & Caine, 1991). This often leads to problems for gifted students: If the content and tasks that have been deemed suitable for their grade level are too easy, they will not be engaged, and as a result, they will not be learning. Brain research provides a physical explanation for students' failure to learn. When tasks are not sufficiently challenging, the brain does not release enough of the chemicals needed for learning: dopamine, noradrenalin, serotonin, and other neurochemicals (Schultz, Dayan, & Montague, 1997, cited in Tomlinson & Kalbfleich, 1998).

Evidence about high-ability students' experiences in school indicates that, typically, they are not being challenged and their learning needs are not being met. Mathematics and science curricula, as they are traditionally taught, are often inappropriate for gifted students because they are highly repetitive and provide little depth (Johnson, Boyce, & Van Tassel-Baska, 1995; Johnson & Sher, 1997). In fact, at the elementary level, a national study found that an average of 35 to 50 percent of the regular curriculum could be eliminated for gifted students (Reis & Purcell, 1993).

We must remember that decisions about grouping are preliminary and that what matters most comes next .... Given poor instruction, neither heterogeneous nor homogeneous grouping can be effective; with excellent instruction, either may succeed.

"Is Ability Grouping Equitable?"
(Gamoran, 1992)

The National Research Center on the Gifted and Talented has conducted extensive research about the instruction that gifted students receive in the regular classroom. In the Classroom Practices Survey, in which researchers gathered data from a sample of 7,000 educators, teachers reported making only minor modifications, if any, for the gifted students in their classrooms (Archambault et al., 1993). The teachers who did report making adjustments usually did so by assigning more advanced reading materials, providing enrichment worksheets, or asking students to complete extra reports. In the Classroom Practices Observation Study, researchers found that in 84 percent of classroom activities, gifted students received no differentiation of any kind (Westberg, Archambault, Dobyns, & Slavin, 1993).

In spite of the available strategies, it appears that teachers are finding it difficult to meet the needs of gifted learners. There are several possible reasons for this, all of them equally valid and powerful. To begin, schools are organized around the idea that students who are the same age will also have the same level of readiness and ability. In addition, teachers have seldom received training in how to differentiate instruction. They often rely on familiar methods rather than choosing strategies based on the needs of the gifted students (Starko & Schack, 1989). Teachers are beginning to receive more training as mainstreaming becomes more prevalent and schools begin to acknowledge students' diversity, but the tradition of one-size-fits-all instruction is pervasive and strong.

Ability Grouping

Ability grouping is a complex and often divisive issue in education. It is difficult to deal with such a complicated subject in the limited space this publication allows. However, as teachers strive to implement collaborative learning strategies and to meet the needs of diverse learners, an overview of the various arguments and research about ability grouping seems essential.

Before delving into the issue, it is important to define the differences between "tracking" and "ability grouping." Tracking is the practice of sorting students into different classes based on their grades, test scores, and perceived abilities. Ability grouping refers to groups organized by the teacher within heterogeneous classrooms.

Critics of gifted education and tracking claim that heterogeneous grouping is necessary in order to ensure equal opportunities for all students. Students who get stuck in low-level tracks are deprived of opportunities to develop higher-level skills and study rich content. Tracking practices have also played a part in preserving the stratification of society, which is demonstrated by the overrepresentaiton of minority and low-socioeconomic students in remedial classes and special education (Oakes, 1990). While they do not support tracking, advocates for high-ability students claim that homogeneous grouping is appropriate at least some of the time in order to meet the needs of gifted students. They worry that a slower pace will fail to challenge students and that these students will miss opportunities to pursue advanced work.

Because of the strong arguments on either side, the ability-grouping issue has generated a great deal of research, much of it inconclusive, about the benefits or weaknesses of heterogeneous and homogeneous grouping. The two most frequently cited studies are meta-analyses conducted by Slavin

(1990) and Kulik and Kulik (1992). Both studies found that ability grouping has essentially no effect on student achievement across all ability levels.

However, some research on ability grouping does indicate that when instruction and materials are tailored to student ability, grouping has a positive effect on student achievement. The instructional strategies that teachers use with groups have a greater effect on achievement than the actual placement itself (Rogers, 1998). Research on schools with inclusive classrooms shows that differentiated instruction is an essential ingredient for success. In a study of "detracked" schools, Gamoran and Weinstein (1998) found that heterogeneous classes were most effective when teachers used differentiated instruction. "High quality instruction relied on individualization, varied expectations (but at a high level for all students), and complex authentic assignments" (Gamoran & Weinstein, 1998).

Ultimately, it is not necessary or realistic to use only one grouping method. Heterogeneous and homogeneous groups can both be effective, depending on the activity and the students. Sometimes, gifted students benefit from the challenge and the extended possibilities of working with other students of similar abilities. Yet they also need to work in heterogeneous groups where they learn from their classmates and have opportunities to deepen their understanding by explaining what they have learned to others. Specialists in gifted education make the following recommendations about grouping students:

- Heterogeneous groups are most appropriate when students are working on open-ended problem-solving tasks or science inquiry activities
- It is also appropriate for students to work in heterogeneous groups when they are discussing concepts that are new to all students
- Homogeneous groups are more appropriate when students are working on skill development or reviewing material that they have already learned
- Grouping strategies should be flexible, and students should be allowed to work independently at least occasionally according to their preferences
- Students should have opportunities to select their own groups based on common interests
- All students need to learn the skills of working together before cooperative learning activities will be successful

(Matthews, 1992; Van Tassel-Baska, 1992)

Providing Challenging Mathematics for All Students

It is a gray and foggy day in Lebanon, Oregon— familiar fall weather in the central Willamette Valley. The students at Seven Oak Middle School are unaffected by the gloomy skies as they bustle into Sue Garnier's eighth-grade mathematics classroom.

In Garnier's classroom, the walls are filled with pictures from all over the world, as well as postcards, foreign currency, masks, and souvenirs. "I try to find things that the students will look at and wonder, 'What does that have to do with math?' Hopefully, they will be inspired to try to figure it out." Garnier loves to travel, often with students. Her room is full of things that she has collected from various parts of the world. A banner on the wall reads: *Mathematics is the language of creation.* "I try to help my students understand that math is much more than just numbers. Math *happens,* math explains the world. Numbers are just the shorthand for writing math down."

> "My approach is to offer opportunities for students to explore mathematics to the level that they want to be challenged, to go as deep as they can go."
>
> —Sue Garnier, teacher

Lebanon is a rural town in Oregon's Willamette Valley near Salem. The decline of the timber industry has transformed the town into a bedroom community, but the storefronts at the heart of Main Street seem to have changed very little in the last 50 years. The depressed economy means that the Lebanon Community School District must struggle to make the best of very limited resources. Seven Oak Middle School is one of two middle schools in the district, serving 340 students in sixth, seventh, and eighth grades.

At Seven Oak, the mathematics classes are not grouped by ability—a districtwide policy. The mathematics classes are also integrated rather than divided into subjects. The teachers combine algebra, geometry, probability, statistics, and other topics whenever possible. Because her classes include students with different ability levels, Garnier has focused her energy on developing strategies for differentiating instruction. "My approach is to offer opportunities for students to explore mathematics to the level that they want to be challenged, to go as deep as they can go. I don't categorize kids as being at just one particular level. What they know and can do may change depending on what we're studying. I look for clues about how they think and what their interests are, and use those to determine the level that they're best suited for."

At the beginning of a unit, Garnier uses a pretest, as well as information from students' discussions and writings, to determine their readiness and areas of strength. "I do receive a list of students every year that the district has identified as talented and gifted. But I rely more on my own observations and what I see in the classroom to guide what types of instruction I give my students." Some students may not be formally identified as gifted, but they are highly motivated. There may be a topic in which they are very strong or that really appeals to them.

Garnier tries to ensure that students are challenged by encouraging them to reason and by asking them higher-level questions. She also provides time for students to ask questions and make choices, and she uses ideas and questions that come up in discussion.

In a typical unit in Garnier's class, the students will start out with an introduction to the topic using the textbook. The series is designed to teach mathematics as an exploratory process. Students work through a series of ideas or steps in order to arrive at a mathematical rule or concept. Students begin with the basic ideas, experimenting with a concept and drawing conclusions. The textbook also provides problems from all different domains and provides many entry points that pull in students' interests.

Today, students are learning about squares and square roots, building an understanding of what a square root really is. The students use their calculators to practice with the new concept. After this exploratory phase, the students use graph paper to draw squares, creating a visual representation of what they did with their calculators.

Garnier provides the students who have a firm grasp of the concept with a different activity. They are using a textbook from a higher grade level to begin exploring rational and irrational numbers. The advanced activity is challenging for the students. One by one, they begin to gather at a table in the back of the room. They discuss the problem, attempting to pool their knowledge.

"What *is* an irrational number?" asks a student.

One of his classmates tries to explain: "It's like pi."

"What do you mean?"

"The number just keeps going," volunteers another.

In a different unit on statistics, students use what they have learned about coordinate grids and data tables to map the ocean floor. Garnier will vary the lesson for students by providing different levels of possible activities. For students who need the concrete ideas to work with and more direction, Garnier will provide students with some data and explain how the students will need to use it to make a map.

Other students may get the concept quickly and be ready to work at a more abstract level. These students may create their own data and identify what part of the ocean it would come from. Or the students might develop a contour map of an area they are familiar with or create a map of a trail they have walked. All the students are learning about taking data and applying it to a physical surface—the same core concept. It is the way in which they go about developing their understanding and the level to which they go that varies.

Garnier uses students' own responses to a challenge to guide the level at which students will work. Most students need to work through basic processes, building on past understanding and clarifying what they know. Others grasp the concept quickly and are ready to go into greater depth, or connect to other ideas. Some are only beginning to understand the concept at its most concrete level, and some are in-between.

Garnier's role is to provide opportunities for each level of learning. "Most students fall clearly into one of the three or four levels. For those who could go to the next-highest level, I basically leave it up to them. If they want to challenge themselves, it's there for them. Some students would accept far less than what they're capable of, which results in boredom and apathy. I will direct those students toward a bigger challenge, but even then, it will be their choice as to how far they go with their ability."

Garnier emphasizes that the students are not all going in different directions and working on different projects. There are clusters of students working on different things—usually two or three (sometimes four or five) different levels of the same basic assignment. The most differentiation takes place when students are working on longer-term projects. At other times, everyone is closer to the same page, with less difference between levels.

"Differentiating instruction is difficult. It is not something I feel that I have mastered, because it requires constantly reflecting on what works with my students and what doesn't." Garnier notes that one of the most difficult parts of differentiating instruction is actually beginning. "I had the advantage of being pushed off the cliff and being told to fly. The year I was hired, Seven Oak (and the district) had made a decision to move toward heterogeneous math groupings. I just started—I made a lot of false starts, but I am persisting. I've also had a lot of really good learning experiences. I didn't even know in the beginning that what I was trying to do was called differentiation. I was just trying to teach in a way that provided a challenge for all, and still keep the powerful advantages that diversity brings to learning groups."

In order to differentiate instruction and meet students' needs across the spectrum of their abilities and interests, Garnier acknowledges that she had to make many changes in her approach to teaching. "I had to make myself let go of the things that made me feel successful as a teacher, things like a quiet, orderly classroom with students working at their desks, practicing the algorithm that I taught them that day. That was hard to do—it was the way I was taught, and how I had always taught math. The problem was, there were just too many students who weren’t putting ideas together, who didn’t understand what they were doing, much less why they were doing it.

“I knew there had to be a better way. Now we—my students and myself—are discovering the huge world of mathematics together. I’m learning and discovering right along with them. Of course, not all of them share my enthusiasm, but I at least get a smile when I say, ‘Look, you guys—this is cool—look at how this works! Did you see how that happened?’”

Strategies for Teaching Gifted Students in the Inclusive Classroom

ALTHOUGH THERE IS A WIDE RANGE OF LITERATURE ABOUT meeting the needs of gifted students in the regular classroom, there are a number of gaps in the research. Experts in gifted education suggest practices that they use and know to be effective, but there is very little research that formally tests their experience and recommendations. Few studies concentrate on gifted students in the regular classroom, and even fewer examine the effects of instructional strategies on both gifted and non-gifted students.

In a review of research on gifted students in the regular classroom, Johnsen and Ryser (1996) describe five overall areas for differentiation: modifying **content**, allowing for **student preferences**, altering the **pace** of instruction, creating a flexible classroom **environment,** and using specific **instructional strategies**. The bulk of the research concentrates on instructional strategies that have been linked to improved student achievement and have been shown to increase critical thinking, problem-solving abilities, and creativity. The following have been established as effective strategies (Johnson & Ryser, 1996):

- Posing open-ended questions that require higher-level thinking
- Modeling thinking strategies, such as decisionmaking and evaluation
- Accepting ideas and suggestions from students and expanding on them
- Facilitating original and independent problems and solutions
- Helping students identify rules, principles, and relationships
- Taking time to explain the nature of errors

One of the most extensive studies on teaching gifted students in inclusive settings is a survey of classroom practices in schools that have a well-established reputation for meeting the needs of gifted students. Westberg and Archambault (1997) compiled case studies of teachers in elementary schools, identifying themes and common approaches to teaching gifted students in regular classroom settings. The following strategies occurred most frequently:

- Establishing high standards
- Making curriculum modifications
- Finding mentors for students
- Encouraging independent investigations and projects
- Creating flexible instructional groups

(Westberg & Archambault, 1997)

The research on which strategies and methods are appropriate for gifted students only and which ones work well for all students is not conclusive. Many of the strategies established by research and recommended by experts are similar to, if not the same as, recommendations from the national standards documents for mathematics and science (National Council of Teachers of Mathematics [NCTM], 1989; National Research Council [NRC], 1996). As is so often the case, teachers are the most reliable experts. They will need to try the strategies for themselves and use their own judgment in determining how well they work for students.

ACKNOWLEDGING THAT STUDENTS LEARN AT DIFFERENT SPEEDS AND THAT THEY DIFFER WIDELY IN THEIR ABILITY TO THINK ABSTRACTLY OR UNDERSTAND COMPLEX IDEAS IS LIKE ACKNOWLEDGING THAT STUDENTS AT ANY GIVEN AGE AREN'T ALL THE SAME HEIGHT: IT IS NOT A STATEMENT OF WORTH, BUT OF REALITY.

How to Differentiate Instruction in Mixed-Ability Classrooms (Tomlinson, 1995)

The Learning Environment

THE PROCESS OF DIFFERENTIATING INSTRUCTION IS MOST effective in a flexible and supportive learning environment, which encompasses both the physical setting of the classroom and its climate. The teacher sustains a relaxed yet challenging environment by encouraging responsibility and autonomy, supporting students' different needs, and emphasizing students' strengths. In addition, sharing responsibility for the classroom climate with students helps to ensure that it is productive and comfortable for everyone.

Classroom Organization and Management

The classroom itself must be organized for flexibility and openness. There will be space for students to engage in a variety of activities, both independently and in small groups. Students are free to move as they need to, as long as they remain on task. They are able to leave the classroom in order to go to the library, for example, or to a resource room or computer lab (Feldhusen, 1993).

What is Differentiated Instruction?

Differentiated instruction is an approach to teaching that is comprehensive and guides teachers in all aspects of their practice. It does not mean grading gifted students harder than other students or assigning extra work to keep students busy (Tomlinson, 1995). It is a continuous process of learning about students' needs and interests and using that knowledge to guide instruction. Teachers use their knowledge of students to determine how content is presented, what activities are appropriate, and how to guide students in demonstrating what they have learned (Tomlinson, 1999). All of the strategies in the following sections are a part of providing differentiated instruction.

When students work on different content, use different learning strategies, and create different products, the teacher takes on an altered role in the classroom. Presenting the curriculum to students is no longer the teacher's primary focus. Instead, she concentrates on creating and selecting learning opportunities for students, guiding them, and working with them to assess their progress.

Giving students choices and allowing them to schedule their activities encourages independence and keeps students engaged (Feldhusen, 1993). It is recommended that students be allowed to choose what they want to work on at least part of the time. Students are still accountable for completing specific activities or demonstrating what they have learned within a certain period of time, but they choose when or how they will work.

The following strategies are helpful in organizing and managing the classroom for differentiated instruction:

- Using "anchor activities" that students can complete with little supervision—tasks such as writing journal entries or working on a portfolio—provides time for the teacher to work directly with other students (Feldhusen, 1993; Tomlinson, 1999).

- When students are working on different activities, it will be helpful to have instructions available for easy access. The teacher may want to create assignment cards rather than giving directions orally or writing multiple sets of directions on an overhead (Tomlinson, 1999).

- Teachers will also need to be sure that all students know how to get help when they need it, either by asking another student, going back to the directions, or working on another task until an appropriate moment for asking the teacher (Tomlinson, 1999). A student might serve as "Expert of the Day" when she has shown a deep understanding of the concept or task.

- Involving the students in creating classroom procedures and rules and in organizing their time helps them to build important skills in decisionmaking, negotiating, and planning. It also ensures that students feel at home and involved in the classroom (Feldhusen, 1993).

Social and Emotional Climate

A nonthreatening atmosphere is important for all students, including high ability learners. Gifted students are often perfectionists, and they may place great significance on getting the right answers or completing tasks quickly. They are sometimes outsiders among their classmates because of their unusual abilities, or they may be accustomed to having a higher status than other students in the classroom.

The foundation of a good learning environment is a feeling of safety and acceptance. Teachers help to create this atmosphere by modeling respect and care for all members of the classroom. Emphasizing every student's strengths is another important element of an effective atmosphere for learning. All students need to feel and recognize the value of the abilities and experiences of themselves and others.

Sometimes gifted students feel insecure when they are presented with open-ended inquiry or problem-solving activities. Students may insist that they need procedures spelled out for them so that they can follow directions and "do it the right way." The teacher might remind students that mistakes are an important part of learning. It is possible to communicate understanding for students' feelings while also being firm about the requirements of the task.

Gifted students may also resist when they are asked to show their work or explain their thinking processes. If they are accustomed to finishing tasks quickly, some students resist what they see as unnecessary work that slows them down. Explain to the students that it is just as important to show how they got an answer as it is to be correct. Using a scoring guide with descriptive criteria helps students understand how their work will be evaluated and articulates high standards.

Support for Gifted Minority Students

Although there has recently been a significant increase in research about identifying gifted students from cultural minority groups, there is not yet comparable attention to the challenge of providing support for gifted minority students. All gifted students may experience isolation and pressure to hide their abilities, but minority students tend to feel the weight of these forces to an even greater degree. Gifted minority students report feelings of inferiority, as well as the need to constantly choose between using their talents and fitting in with their peers (Cropper, 1998).

Providing students with extra support is especially important in mathematics and science. In these fields, cultural stereotypes have contributed to the underrepresentation of minorities. Although there is not yet a substantial body of published research, there are many suggestions and strategies developed by educators for meeting the needs of gifted minority students:

- Communicate high expectations.
- Be sensitive to the experiences and beliefs of people from different cultural groups. Get to know all students and their cultures. Consider the challenges that students may face in school.
- Continuously and firmly encourage students to go to college. Discuss the necessary coursework, tests, and other preparations with students and parents.
- Create a multicultural learning environment and make sure the curriculum reflects a variety of cultures.
- Help students connect with role models and mentors. Organize peer support groups for students with similar interests and abilities.
- Reach out to parents and family members. Enlist their support in providing encouragement and high expectations.
- Provide students with a variety of learning options. Create or select activities that are engaging, active, and grounded in reality.
- Listen to students' concerns, fears, and beliefs about their experiences and their education.

(Cropper, 1998; Ford, 1996)

Support for Gifted Girls

Gifted female students face many unique challenges and problems that tend to undermine their abilities and potential. Gifted girls do not achieve at expected levels, especially in middle school and high school, and they often do not pursue careers appropriate to their abilities (Badolato, 1998). Researchers have identified a number of reasons for female students' underachievement: gender stereotypes pervasive in society, lack of role models, declining confidence in their abilities, mixed messages and conflicting expectations from teachers and parents, and peer pressure to hide their abilities and intelligence (Smutny & Blocksom, 1990).

More specifically, teachers often have less tolerance for girls who call out answers in class, ask numerous questions, and are confident in their opinions and willing to argue—behaviors that are likely to be accepted as evidence of giftedness in boys (Kerr, 1994). Often girls are socialized in school and at home to be attractive, obedient, caring, agreeable, and submissive. As a result, girls have a tendency to hide their intelligence and downplay their abilities in order to conform to the socially accepted stereotypes of femininity (Ryan, 1999).

To counteract the forces that work against gifted girls' achievement, teachers and parents must become aware of their biases about gender and appropriate behavior for females. It is also important to strike a balance between encouraging girls to pursue nontraditional fields while not devaluing traditional female strengths and interests. Some recommended practices in meeting the needs of gifted girls include:

- Communicate with parents about their daughter's abilities and the importance of mathematics and science for higher education and careers. Encourage them to identify and address sources of gender bias.
- Organize peer support groups for girls. Mathematics and science clubs encourage girls to develop their skills and abilities and help connect them to other girls who share their interests.
- Avoid praising girls for their neatness or behavior. Point out specific examples of their excellent work and achievements. Actively correct them if they attribute their accomplishments exclusively to luck or hard work.
- Provide opportunities for girls to use their leadership abilities.
- Expose students to women in nontraditional careers. Help them to identify and connect with role models and mentors.

> GIFTED GIRLS ASSUME ALL SORTS OF EXTRA BURDENS THAT EDUCATORS NEED TO UNDERSTAND. FEW GIFTED GIRLS KNOW THEY ARE TALENTED. THEY KNOW ONLY THAT THEY ARE DIFFERENT AND THAT THIS DIFFERENCE IS SOMEHOW WRONG OR WEIRD.
>
> *Gifted Girls* (Smutny, 1998)

- Openly discuss gender stereotypes and the mixed messages that society broadcasts about femininity, intelligence, and achievement.

- Provide a safe environment for girls to share their confusion and fears.

- Actively recruit girls to participate in advanced courses and extracurricular activities related to mathematics, science, and technology.

- Encourage students to research and report on female contributions to mathematics and science.

(Davis & Rimm, 1994; Smutny, 1998)

Differentiating Content

Making modifications to mathematics and science content is one aspect of in providing challenging learning opportunities. Gifted educators recommend that science curriculum for high-ability students should move at a faster pace and feature less repetition. It should also allow students to delve into important ideas and thought processes (Boyce et al., 1993). In mathematics, students should study advanced content in earlier grade levels (Johnson & Sher, 1997).

Organizing the curriculum around major themes and ideas is one of the first steps in differentiating content. Using broad concepts helps to create opportunities for students to learn and apply integrated and complex ideas (Berger, 1991). Some key themes in mathematics include functions, patterns, scale, rates, and change (Johnson & Sher, 1997). Systems, models, reductionism, and evolution are among the major concepts in science (Van Tassel-Baska, Bailey, Gallagher, & Fettig, 1993). The following publications may be helpful in identifying other major themes and concepts in mathematics and science: *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993), *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989), and *National Science Education Standards* (NRC, 1996).

It is important that mathematics and science content focus on more than computation, formulas, and vocabulary. All students benefit from a curriculum that does not focus exclusively on basic skills. A broader focus allows students who may not have strong computation or memorization skills to demonstrate their abilities in abstract reasoning, creativity, and conceptual understanding. There are different methods for encouraging students to move beyond the basic concepts of the mathematics and science curriculum.

One recommendation for differentiating content for gifted students is increasing the level of abstractness and complexity (Maker & Nielson, 1996). For example, students might study a concept at the theory level: identifying and testing mathematical or scientific laws or connecting seemingly

Key Components of Mathematics Curriculum for the Gifted

- Content with greater depth and higher levels of complexity
- A discovery approach that encourages students to explore concepts
- Focus on solving complex, open-ended problems
- Opportunities for interdisciplinary connections

(Johnson, 1993)

Key Components of Science Curriculum for the Gifted

- Significant and deep content
- Emphasis on understanding concepts rather than memorizing facts
- An inquiry approach with students as active investigators
- Opportunities for interdisciplinary connections
- Investigating real problems and situations
- Guiding students toward scientific habits of mind

(Van Tassel-Baska, 1994)

disparate ideas. Students might learn about or develop complex systems that have many sections and processes.

Adding variety to the content that students work with is another important strategy. Students are exposed to new materials, books, tools, and people, which helps to stimulate curiosity and creativity. Gifted students might work on projects in which they investigate the history of an idea or generate formulas or laws from their own observations (Tirosh, 1989). Adding topics that are not part of the regular curriculum can also be effective. For example, in mathematics, students might learn about transformational geometry, topology, number theory, and logic (Wilmot & Thornton, 1989).

Bloom's Taxonomy of Educational Objectives can be helpful in designing content for gifted students (Bloom, 1956). Bloom's six levels of knowledge are knowledge, comprehension, application, analysis, synthesis, and evaluation. The final three levels are most appropriate for gifted students and may help teachers to identify ways for students to work with content in more advanced and more challenging ways (Smutny & Blocksom, 1990). Analysis involves using content to classify, compare, contrast, investigate, and deduce information and ideas. Synthesis will require students to use ideas and knowledge to create original work, using it to invent, design, and plan—for example, developing a theory or hypothesis. Evaluation requires students to interpret, verify, criticize, defend, and judge ideas and information.

One of the simplest ways to present more challenging content is to provide advanced materials for gifted students. Textbooks, tradebooks, and other resources from higher grade levels or even written for adults will help provide more complexity and will often be more appropriate (Maker & Nielson, 1996). Teachers might want to provide library books on the subjects the class is working on or on related topics. Students might also use a list of suggested resources to find and select their own materials. It will also be helpful to provide mathematics or science texts from higher grade levels or even from the college level.

Curriculum Compacting and Flexible Pacing

Curriculum compacting is a method of differentiating content for high-ability learners developed by Renzulli and Reis (1998). There are three basic steps: pretesting students at the beginning of a unit, eliminating content or skills that students already know, and replacing the skipped content with alternative topics or projects.

In order to plan for curriculum compacting, the teacher analyzes an upcoming unit to determine the key concepts and skills. Next, she selects the best way to identify students who have already met the learning objectives. The choice of pretest will depend on the type of knowledge or skills that need to be assessed. Some options include unit tests, essay questions, brief interviews, and observations (Reis & Renzulli, 1992).

Students who demonstrate their proficiency on a pretest will collaborate with the teacher to select alternative activities. Students may use the time to work on independent projects of their own design. Or the teacher might assign an enrichment activity that the class is not yet ready to pursue. The students who complete the activity may wish to act as advisors when the whole class is ready to begin (Smutny et al., 1997).

Sometimes there will be specific areas in which the student is still developing skills. In this case, the teacher might ask the student to rejoin the class at certain points during the unit. Alternatively, the student might complete skill-building activities on her own. The student may also need to join the class for discussions and problem-solving or inquiry activities.

Curriculum compacting should be an option for all students in the classroom, not just those labeled "gifted" (Renzulli & Reis, 1998). Students who have strengths in a particular content area or who have studied a topic that they are interested in on their own time will benefit from having an opportunity to pursue other activities.

Another strategy for changing the pace of the curriculum is called "Most Difficult First" (Winebrenner, 1992), and it is most appropriate for mathematics. Students are allowed to work on the five most difficult problems instead of completing the whole assignment. If the students are successful, they are allowed free time or are asked to work on an alternative activity (Winebrenner, 1992). Again, this option is available to all students in the class.

Flexible pacing means that students are allowed to work at the level most appropriate to their abilities (Miller, 1990). There are several ways to provide students with suitable options. Advanced students might join higher-level classes in mathematics or science. A group of students might move through material at an accelerated pace. Or high-ability students might be allowed to work independently at their own pace (Daniel, 1989).

As they plan for flexible pacing, teachers will probably find it necessary to consult with their colleagues who teach higher grade levels or advanced classes. Their guidance will help to identify the advanced content and skills that students learn. They will also need to be aware of the students who have been working at an accelerated pace when those students join their classes in the future (Conroy, 1993).

Models for Differentiating Content

The Enrichment Triad Model (Renzulli & Reis, 1986) is intended to guide the development of enrichment activities, but it can also be used as a method for structuring a unit for the whole class. The model consists of three sequential levels of activities that are increasingly challenging and complex. Type One activities are exploratory and expose students to new topics. The primary purpose of these activities is to engage students and spark their interest. Some possible activities include demonstrations, guest speakers, field trips, and exploration through open-ended discovery tasks (Renzulli & Reis, 1986).

Type Two activities are designed to help students learn and develop the information and skills related to the subject of the unit. They will involve such concepts and skills as problem solving, critical thinking, interviewing, analyzing and organizing data, and communicating orally and in writing (Renzulli & Reis, 1986). These skills are often needed for the next level, Type Three activities, which are very challenging and require a high level of creativity and persistence. Students become first-hand inquirers and experimenters, working as if they were professional scientists or mathematicians, and creating authentic products (Renzulli & Reis, 1986).

The Cognitive-Affective Interaction model was designed to help students develop the skills for divergent and creative thinking (Williams, 1986). Williams defines eight factors—four cognitive and four affective—needed for divergent thinking. The four cognitive qualities are fluent thinking, flexible thinking, original thinking, and elaborative thinking. Risk-taking, complexity, curiosity, and imagination are the four affective qualities (Williams, 1986).

Williams also suggests 18 teaching approaches that will encourage creative thinking and that can be used across the disciplines. The following are some of the strategies from the model:

- Present students with **paradoxes** to analyze and test
- Use **analogies** to introduce new concepts; ask students to create their own
- Allow students to think about **discrepancies** in what is known

- Ask **provocative questions** and provide time for inquiry
- Examine **examples of change** and the process of change
- Use **examples of habit** and the results of habit-bound thinking
- Encourage **tolerance for ambiguity** with open-ended problems
- Encourage students to use their **intuition** and follow their hunches
- **Study creative people** and their thinking processes
- **Evaluate situations** by analyzing possible consequences and implications
- Help students practice **creative reading, listening, and writing** skills

(Williams, 1986)

Knowing Your Students Is the Key

GINGER REDLINGER TEACHES SCIENCE AND MATHEMATICS at Inza Wood Middle School in Wilsonville, Oregon, a town in the southern metropolitan area of Portland. Wilsonville is a rapidly growing area, the home to a variety of high-tech companies, including Tektronix, Mentor Graphics, and In Focus. There are approximately 500 sixth-, seventh-, and eighth-grade students at Inza Wood Middle School.

Redlinger sees a wide range of abilities and interests in her students. While some are formally identified as being gifted by the school district, she finds that this identification is not as meaningful as her own knowledge of her students. "The most important part of differentiating instruction is getting to know your students. Once you see how different your kids really are, you can't really go back to a single approach."

> "I STARTED OUT USING MULTIPLE ASSESSMENTS, PROVIDING STUDENTS WITH A VARIETY OF WAYS TO SHOW WHAT THEY HAD LEARNED: TAKING A TEST, WRITING AN ESSAY, CREATING A MURAL. I LEARNED SO MUCH FROM THESE ASSESSMENTS THAT I THOUGHT, 'IMAGINE WHAT WOULD HAPPEN IF I USED MULTIPLE ACTIVITIES THROUGHOUT A UNIT.'"
>
> —Ginger Redlinger, teacher

Redlinger uses learning styles and multiple intelligences as the basis for differentiating science instruction. "I started out using multiple assessments, providing students with a variety of ways to show what they had learned: taking a test, writing an essay, creating a mural. I learned so much from these assessments that I thought, 'Imagine what would happen if I used multiple activities throughout a unit.'" After finding out how students learn best—writing, drawing pictures, reading, using graphic organizers—Redlinger then creates a menu of instructional options.

At the beginning of a unit, Redlinger uses a pretest to establish what students already know about the topic area. Pretesting is important because she finds that her students' abilities often vary from unit to unit—there are not established groups of high-ability or low-ability students. All students have the option of testing out of a unit. "I create a science pretest by looking at the key concepts of a unit and asking myself what the students really need to know."

After the pretest, students can choose from multiple paths and activities, selecting options based on their abilities, interests, and learning styles.

Redlinger requires students to record their activities in a planner and checks in with them weekly to monitor their learning. Students who test out of a unit can choose alternative activities, including team projects. They use a learning contract to plan their work and record their progress.

This year, most of Redlinger's students tend to be either kinesthetic learners or language-based learners. Therefore, the projects they work on are usually based on either writing or building a model. "The students are more engaged and excited about what they are learning," says Redlinger. She emphasizes that it is important that the projects are equal in the amount of work and time that go into them.

Students in Redlinger's classes often work on group projects, and she uses both mixed-ability and like-ability groups. "I decide how to group students depending on how close the students are in ability. Sometimes they are very close and other times there is a much broader range. I also take into account the type of activity that students will be doing. For a problem-solving activity, in which students benefit from multiple perspectives and strengths, I will use mixed-ability groups."

The flow of a typical science unit incorporates a variety of activities, and Redlinger provides opportunities for students to make choices about their learning. For example, a unit about the behavior and patterns of matter begins with the whole class discussing patterns that are found in nature. The students identify patterns that they are interested in, such as spirals, bubbles, or hexagons. They discuss their patterns in small groups, rotating through different groups and explaining their patterns in each one. Finally, the groups report back to the whole class, and they display the patterns on the wall.

Redlinger then guides students toward ideas about transformations of shape and the role of atoms. The students again work in small groups, conducting experiments with phase changes. After the lab work, Redlinger asks the students to choose a topic that they want to learn more about. The students choose to research storms, connecting back to the patterns they studied with the spiral of the tornado. In this part of the unit, students do research in the textbook about the behavior of atoms and the physics of storms in order to develop a common understanding. They reinforce their learning with different activities—creating a game board, a collage, an essay, a children's book, or a research project. Finally, the unit concludes with students sharing their projects with the whole class.

To make a differentiated approach work, Redlinger believes that teachers need time and support from other teachers: giving each other feedback, sharing useful resources, and even just listening to frustrations. She suggests that teachers begin by setting aside some time to think about strategies for differentiating instruction and to plan just one activity. She also recommends that teachers organize their instruction around broad concepts, which makes it easier to tie different activities together.

Finally, an important part of differentiating instruction is allowing students to make choices and select their activities. Redlinger stresses that while this may seem difficult to manage at first, it has enriched her teaching. "Sometimes we go where I want to go. Sometimes we go where the students want to go. And nine times out of 10, where they want to go turns out to be *better* than what I had planned. That was a lesson in humility at first, but it is such a powerful and exciting experience for the students and for me."

Differentiating Processes

Self-Directed Learning

Independence is often cited as a characteristic of gifted students. But that does not mean all gifted students have the skills for self-directed learning. Students will be at different levels of readiness. If students struggle with making choices or planning their work, it does not mean they are not ready and that they must go back to teacher-directed activities. Students will never be ready unless they have opportunities to learn how to take responsibility for their learning (Pirozzo, 1987).

Self-directed learning is not a single strategy, such as allowing students to choose topics for independent study, but a range of methods. The appropriate strategies will depend on students' levels of readiness. Some students will be able to choose their own topics for study or design a final product, while other students will need a list of ideas from which to choose.

There are a number of basic skills of independent learning, such as making choices, planning, setting goals, identifying resources, and self-evaluating (Tomlinson, 1993). As students practice and master these skills with guidance from the teacher, they will be able to become increasing independent. Students who already demonstrate the skills of self-guided learning will benefit from opportunities to pose questions or problems to investigate, decide what activities will further their knowledge, choose products to demonstrate their learning, and monitor their own progress toward their goals (Tomlinson, 1993).

Self-directed learning does not mean that students work in isolation or are not accountable for their learning. The primary goals of self-directed learning are for students to be able to: make decisions based on self-knowledge, assume responsibility for completing their work at an acceptable level and in a timely manner, seek and articulate problems and determine a method for solving them, and evaluate their own work (Treffinger & Barton, 1988).

George Betts developed the Autonomous Learner Model to help gifted students develop the skills of independent learning. The model has five stages or dimensions:

1. **Orientation.** Students develop an understanding of their abilities, skills, interest, and learning styles.

2. **Enrichment activities.** Students are exposed to a wide range of content areas, including cultural activities and field trips, and discuss their emerging interests.

3. **Seminars.** Students explore topics of interest in small groups.

4. **Individual development.** Students learn skills for problem solving, goal setting, creativity, and self-assessment, as well as knowledge about careers and interpersonal skills.

5. **Indepth study.** Students pursue their individual interests and become producers of knowledge, often conducting original research.

(Betts & Neihart, 1986; Feldhusen, Van Tassel-Baska, & Seely, 1989)

One of the central issues of self-directed learning is ensuring that students are learning the knowledge and skills that they will be accountable for, especially with standards and benchmarks in place. One strategy is to use agendas for students, outlining the activities they will be responsible for completing and the skills they will be expected to develop within a certain time frame, usually two or three weeks (Tomlinson, 1999). The student is responsible for deciding when to complete the items on the agenda. The agendas should be adjusted to students' rates of learning and ability levels, but that does not mean that each student in the class must have a tailor-made agenda.

Agendas are most appropriate for students who are still developing the skills of self-directed learning. For students who are more autonomous, the teacher will be able to let them develop their own agendas. Students can make choices about how they will learn the content and skills, and come up with a plan and a timeline. The teacher will then approve or suggest revisions to the plan and help students monitor their progress.

Learning Centers

Learning centers are a means of enriching and adding variety to the curriculum when they feature advanced materials and activities. Interest-based or enrichment centers can be used to introduce students to a topic or to allow them to pursue challenging activities independently. A teacher might create two centers on the same topic with different types of activities.

In planning learning centers that will challenge gifted students, the first step is to look over the curriculum for possible topics and to take a survey of student interests. The teacher might look for topics that are connected to but not usually included in the curriculum. The activities should be challenging and address students' learning styles and preferences—for example, thought-provoking essay questions, suggestions for experiments, and open-ended problems or projects (Lopez & MacKenzie, 1993).

Some teachers organize learning centers around multiple intelligences, especially at the elementary level. These centers provide a range of books, materials, and tools selected to engage students' interests and encourage them to develop their abilities. A mathematics center might include puzzles, dice, games, calculators, blocks, and problem-solving activities. A center for students who are interested in science might have magnets, mirrors, thermometers, magnifying glasses, models, and questions to ponder (Smutny et al., 1997).

Other learning centers are more specific and focused. A learning center about tessellations may be appropriate for a unit in which students are studying geometry or patterns. The center will have pictures, puzzles, and tiles that all students will find interesting. In addition, the teacher can provide some advanced activities, such as reading and writing about the history or the uses of tessellations, discovering the different types of tessellations and drawing examples, or solving some problems involving translating and transforming tessellations (Cantey, 1988).

Students can also create learning centers for their classmates as independent projects. Students should choose a topic they are interested in or knowledgeable about that they would like to share with the other students. They will be responsible for designing the visual display, writing materials, creating activities, and gathering resources. When the project is complete, the student can briefly introduce the center to the class.

Problem-Based Learning

Problem-based learning is a type of problem solving in which students are presented with an "ill-structured" problem. This type of problem resembles a real-life situation—students do not have all the information they need to solve the problem and the steps they need to take are unclear (Gallagher, Stepien, Sher, & Workman, 1995). In fact, the students' first tasks are to determine what the problem is and to make decisions about how they will approach it. For example, the students are presented with blueprints and building specifications and must determine if the plans are compliant with local codes and rules, as well as how to make changes in the plans to make the building meet the regulations (Boaler, 1998).

After presenting the problem situation, the teacher leads the class or group in defining the problem by centering discussion on three questions: What do you know? What do you need to know? How can you find out? (Gallagher et al., 1995). The students will return to these questions throughout the process as they continually redefine the problem in light of new knowledge. They will also identify the research they need to do as they go along—tasks such as analyzing numerical data, performing experiments, conducting surveys, or contacting experts.

Students usually work in groups to solve the problem. They are responsible for identifying additional data and resources that they need, as well as determining which group members will focus on which parts of the problem. The students will be responsible for deciding how to present their findings and demonstrate their learning. The groups might create presentations, produce exhibits, write reports, make videos, or put together portfolios of their processes and the work they completed (Burruss, 1999).

In problem-based learning, the teacher is not the expert and does not provide students with information or outline processes to use (Van Tassel-Baska et al., 1993). The teacher's role in problem-based learning is that of "metacognitive coach," thinking out loud with students and guiding them toward the questions they need to ask. The teacher also helps students in planning how to go about their work, analyzing their progress as they discover new information, and questioning their assumptions.

An ill-structured problem is an excellent way to introduce a new area of study to students. Instead of presenting students with a problem at the end of a unit, students begin their learning with a problem. The information they will need and the skills they must develop now have context and relevance (Gallagher et al., 1995).

The open-ended nature of problem-based learning activities allows for differentiation in a number of ways. Students can combine their strengths, choosing areas of the problem to concentrate on according to their preferences and abilities. Students will decide how much information they want to work with, how complex their solutions will be, and how they will demonstrate their learning. The teacher can also provide varying levels of guidance. Some students will need more assistance with defining the problem and planning their work.

Planning problem-based learning activities can be a complex and time-consuming process. Teachers will probably want to work together to create problems and share their instructional strategies. The following steps are recommended for creating ill-structured problems:

- Identify some complex issues or problem situations, such as city planning, environmental preservation, or creating a budget.

- Look for examples in books, television programs, and newspaper or magazine articles.

- Align possible problems with curriculum and standards. What areas of the curriculum are involved in the problem? What are the skills that students will use as they analyze the problem and suggest solutions?

- Plan for the best times to present the problem(s) to students. Make sure to allow sufficient time for students to do their work.

- List some of the materials and resources students may need.

- Write up a problem statement that is engaging for students and that puts the situation in an interesting context. The statement should not provide students with all of the information they will need, but suggest directions that they should pursue.

- Revise as you go.

(Burruss, 1999)

Seminars

Seminars are small groups of students within a class in which students have opportunities to learn more about topics that are not covered by the regular classwork. The content of the seminar can expand on a topic that students have learned about in class. It can also be an opportunity for students to learn more about a branch of science or mathematics that is outside the standard curriculum or to delve into science-related issues, such as ethics (Kolloff & Feldhusen, 1986).

The purpose of the seminar is to stimulate students' curiosity and interest and to encourage them to become active participants. The students should determine the scope and activities of the seminar, with the teacher serving as an advisor and guide. The students select the ideas they will discuss, the questions they will pursue, the overall timeline of their work, and what final products they will produce to demonstrate what they have learned.

Teachers can organize seminars in different ways depending on what works best for their classes. The group can meet several times a week or only once. A group of teachers may want to coordinate their efforts by grouping students from several classes together, especially for seminars on interdisciplinary topics. There is no set length of time that the seminar must last, but there should be sufficient time for students to pursue the topic indepth. Some teachers offer seminars as a regular part of their teaching, changing the topic every grading period or semester.

The seminar meetings can be scheduled for times when other students are working on content that the seminar members have already mastered, or when all students are pursuing independent learning activities. Membership in the seminar group should be open to all students, but the con-

tent and expectations must remain challenging. Students may choose to join a seminar on a topic in which they are highly interested.

Studying the use of mathematics in art and architecture is a possible topic for an interdisciplinary mathematics seminar. Students might study the way mathematical concepts are used in quilt patterns, the work of M.C. Escher, the Golden Section, and architectural designs (Kolloff & Feldhusen, 1986). Possible topics for science seminars include the ethics of science, solutions to world hunger and famine, and the ways the mainstream media report medical research. Science seminars might also focus on research processes, acting as a forum for students to describe and discuss their independent research projects, critiquing each other's work (Mackin, Macaroglu, & Russell, 1996).

Differentiating Products

AN IMPORTANT ASPECT OF TEACHING GIFTED STUDENTS IS helping them create large-scale, complex products (Parke, 1989). Products that require students to stretch their abilities and extend their knowledge provide authentic and challenging learning experiences, as well as meaningful assessments.

Gifted education specialists suggest that the products students create should be similar to those created by professionals (Maker & Nielson, 1996). They should address real problems and be intended for real audiences. Whenever possible, the products should be evaluated by experts in the field—for example, college professors, researchers, or other professionals (Tomlinson, 1995).

In addition, students should be allowed to choose products that will enable them to use their strengths as they demonstrate their learning. Products that fit a student's learning style and preference will be more effective than requiring all students to complete a test. For example, students might wrap up a science unit by creating a product for "publication" that will communicate what they have learned, such as news articles, technical reports, letters, or drawings based on their findings from an inquiry activity (Bull, 1993).

An important goal for gifted students is that their products require them to transform information. In other words, the students do not merely repeat what they have learned but create a new idea or product. Products can also become more challenging when students must use advanced materials, conduct original research, or work with primary documents (Tomlinson, 1995).

Self-evaluation is also an essential aspect of using final products. In collaboration with the teacher, students should develop the criteria for judging their own work. They should also be responsible for finding and correcting their mistakes, as well as discovering methods to verify their work.

Conclusion

IT IS WORTH REPEATING THAT MOST OF THE STRATEGIES presented in this publication will be effective for all students in the classroom. This idea is essential in providing opportunities for all students to learn challenging mathematics and science and to demonstrate their strengths and talents. Differentiating instruction is a challenging process. Teachers will need both time and support as they adapt the strategies according to their students and their own teaching styles. The following pages include resources that teachers may find helpful for meeting the needs of gifted students in mathematics and science.

Resources and Bibliography

Resources for Further Reading

Boyce, L.N., Bailey, J.M., Sher, B.T., Johnson, D.T., Van Tassel-Baska, J., & Gallagher, S.A. (1993). *Curriculum assessment guide to science materials.* Williamsburg, VA: College of William and Mary, Center for Gifted Education.

This evaluation system provides schools with a template for reviewing new science curriculum materials. It includes a set of standards to examine general curriculum design features, exemplary science features, and ideas for tailoring activities for high-ability learners.

Johnson, D.T., & Sher, B.T. (1997). *Resource guide to mathematics curriculum materials for high-ability learners in grades K-8*. Williamsburg, VA: College of William and Mary, Center for Gifted Education.

This annotated list of materials includes a selection of textbooks, supplementary units, games, software, and web sites that are appropriate for mathematically able students. The guide also lists the criteria that were used to select materials.

Milgram, R.M. (1989). *Teaching gifted and talented learners in regular classrooms*. Springfield, IL: Charles C. Thomson.

This book includes specific chapters dedicated to strategies for teaching mathematically and scientifically gifted students.

Sheffield, L.J. (Ed.). (1999). *Developing mathematically promising students*. Reston, VA: National Council of Teachers of Mathematics & Washington, DC: National Association for Gifted Children.

This publication explores effective learning environments, national and international trends, and current research on teaching gifted students.

Sher, B. (1993). *A guide to key science concepts*. Williamsburg, VA: College of William and Mary, Center for Gifted Education.

The author discusses seven science concepts deemed to be critical for study by high-ability learners. Individual sections explain the significance of the concepts to science inquiry and the application of the concepts to teaching and learning at K-8 levels.

Smutny, J.F., Walker, S.Y., & Meckstroth, E.A. (1997). *Teaching young gifted children in the regular classroom: Identifying, nurturing, and challenging ages 4-9*. Minneapolis, MN: Free Spirit.

This guide emphasizes strategies for creating learning environments that support all students. It includes practical strategies and techniques, as well as many reproducible handouts.

Thornton, C.A., & Bley, N.S. (1994). *Windows of opportunity: Mathematics for students with special needs*. Reston, VA: National Council of Teachers of Mathematics.

This resource is designed to assist teachers in nurturing the abilities of gifted students to think mathematically through appropriate, relevant, problem-centered instruction. It addresses the National Council of Teachers of Mathematics standards, as well as issues, promising practices, and challenges in teaching mathematically gifted students.

Tomlinson, C.A. (1995). *How to differentiate instruction in mixed-ability classrooms*. Alexandria VA: Association for Supervision and Curriculum Development.

Tomlinson, C.A., (1999). *The differentiated classroom: Responding to the needs of all learners*. Alexandria, VA: Association for Supervision and Curriculum Development.

These resources provide practical guidance in addressing the diverse needs of students in mixed-ability classrooms. Both books provide multiple approaches to content, process, and product. The 1999 publication is more comprehensive and includes many detailed examples of teachers using differentiated instruction.

Van Tassel-Baska, J., Bailey, J.M., Gallagher, S.A., & Fettig, M. (1993). *A conceptual overview of science education for high ability learners*. Williamsburg, VA: College of William & Mary, Center for Gifted Education.

This concept paper outlines key curriculum components for K-8 high-ability learners and includes a summary of background research and rationale.

Winebrenner, S. (1992). *Teaching gifted kids in the regular classroom: Strategies and techniques every teacher can use to meet the academic needs of the gifted and talented*. Minneapolis, MN: Free Spirit.

This guide presents specific strategies with step-by-step instructions and scenarios to illustrate the strategy in action. It also includes many reproducible materials.

In addition to these books, the National Science Teachers Association publishes *Quantum,* a bimonthly magazine of mathematics and science aimed at high school and college students. The articles present complex problems and sophisticated concepts that will challenge gifted students.

Organizations

Center for Gifted Education
College of William and Mary/School of Education
P.O. Box 8795
Williamsburg, VA 23187-8795
(757) 221-2362
Web: www.wm.edu/education/gifted.html

In addition to a number of enrichment programs, the center publishes curriculum guides for mathematics and science, as well as a number of science modules for gifted students.

Center for Talent Development
School of Education and Social Policy
Northwestern University
617 Dartmouth Place
Evanston, IL 60208-4175
(847) 491-3782
Web: ctdnet.acns.nwu.edu/

The center offers programs for identifying, nurturing, and developing the gifts of students ages four to 18. It provides publications and conferences, as well as summer academic opportunities for gifted students.

ERIC Clearinghouse on Disabilities and Gifted Education (ERIC EC)
The Council for Exceptional Children (CEC)
1920 Association Drive
Reston, VA 20191
1-800-328-0272
Web: ericec.org/

This ERIC Clearinghouse gathers and disseminates the professional literature, information, and resources on the education and development of individuals of all ages who are gifted. It provides ERIC Digests, mini-bibliographies, e-mail discussion groups, and links to other resources, as well as a searchable online database of gifted education programs.

Institute for the Academic Advancement of Youth
Johns Hopkins University
3400 N. Charles Street
Baltimore, MD 21218
(410) 516-0337
Web: www.jhu.edu:80/~gifted/

The Institute provides out-of-school educational opportunities, research on gifted students, conferences, publications, and other resources.

National Research Center on the Gifted and Talented (NRC/GT)
University of Connecticut
362 Fairfield Road, U-7
Storrs, CT 06269-2007
(860) 486-4676
Web: www.gifted.uconn.edu/nrcgt.html

The Center conducts and disseminates qualitative and quantitative research on gifted education. Resources available include a newsletter, conferences, publications, and other products.

Online Resources

Center for Problem-Based Learning
www.imsa.edu/team/cpbl/cpbl.html

This site provides a thorough overview of problem-based learning, as well as information about creating ill-structured problems and examples.

Gifted and Talented Education Resources
www.millville.cache.k12.ut.us/tag/

This is a guide to articles, publications, schools and programs, and fun challenges for students.

Gifted Resources Home Page
www.eskimo.com/%7euser/kids.html

This site contains links to publications and articles, enrichment programs, talent searches, summer programs, and other resources.

Hoagies' Gifted Education Page
www.hoagiesgifted.org/

An extensive Web site features research about gifted students, information for parents and teachers, and lists of both print and Internet resources.

Invention and Design
jefferson.village.virginia.edu/~meg3c/id/id_home.html

This site is geared towards promoting a better understanding the principles of the invention and design process, and includes a set of active learning modules that employ a "hands-on" approach.

Math Forum
forum.swarthmore.edu/

Hosted by Swarthmore College, this site includes mailing lists, discussion areas, ask-an-expert services, an Internet Mathematics Library of resources, and a challenging Problem of the Week.

MegaMath
www.c3.lanl.gov/mega-math/welcome.html

This project makes "unusual and important" mathematical ideas accessible for elementary students, a good source of enrichment ideas and activities.

Odyssey of the Mind
www.odysseyofthemind.com

The Odyssey of the Mind competitions involve creative and divergent problem solving. The Web site includes a number of sample problems, information about developing skills for creative thinking, and profiles of great thinkers from history.

SciEd: Science and Mathematics Education Resources
www-hpcc.astro.washington.edu/scied/science.html

This index of Web sites includes a wide variety of science topics, including ethics, science in the news, the history of science, and pseudoscience.

Science Hobbyist
www.eskimo.com/~billb/

This site has an extensive list of interesting science topics, including "cool science" and "weird science," with books, demonstrations, projects, resources, and much more.

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