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ABSTRACT

On February 24, 1998, results from the final segment of the Third International Mathematics and Science Study (TIMSS), the most comprehensive mathematics and science study ever undertaken, were released. The resultant data brought into focus the dire need for a shift in the U.S. educational paradigm. A framework for a performance-based mathematics program that is challenging, focused, and relevant is an essential part of that needed paradigm shift. The National Council of Teachers of Mathematics (NCTM) Principles and Standards provides that framework. Principles and Standards recommends that instruction be more than mastery of facts and routine skills, but that it result in all students gaining understanding and the ability to apply mathematical concepts in new situations. This paper clarifies how performance-based learning supports the NCTM recommendations and provides a brain-compatible methodology for mathematics instruction. (Author/NB)

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PERFORMANCE-BASED LEARNING AND THE NCTM RECOMMENDATIONS

Abstract

On February 24, 1998, results from the final segment of the Third International Mathematics and Science Study (TIMSS), the most comprehensive mathematics and science study ever undertaken, were released. The resultant data has brought into focus the dire need for a shift in the U.S. educational paradigm. A framework for a performance-based mathematics program that is challenging, focused and relevant is an essential part of that needed paradigm shift. The NCTM *Principles and Standards* provide that framework. These *Principles and Standards* recommend that instruction be more than mastery of facts and routine skills; that it result in all students gaining understanding and the ability to apply mathematical concepts in new situations. This paper clarifies how performance-based learning supports the NCTM recommendations and provides a brain-compatible methodology for mathematics instruction.

Performance-Based Learning and the NCTM Recommendations

Diane Ronis, Ph.D.

In the early 1980s, the public view of student achievement was rather dismal. By 1983 the publication of the report, *A Nation at Risk* (National Commission on Excellence in Education, 1983) made it clear that the United States was experiencing a crisis within its educational system. The purpose of A Nation... was to analyze the 'quality' of U.S. education as it then existed. The result, however, was the initiation of dramatic changes for "traditional" public education and a national preoccupation with the attempt to quantify educational achievement and assess accountability.

Today America's educational system still remains 'at risk'. Some 23 million American adults continue to be functionally illiterate by the simplest tests of everyday reading, writing, and comprehension. What is occurring now is a crisis of accountability. Since the *Nation...* report depicted the "rising tide of mediocrity" in America's schools, some improvements have taken place. More students are going on to college than ever before. SAT scores are on the rise, and fourth grade students have performed well on international comparison tests. However, despite these few bright spots, current indicators paint a disappointing picture overall of the preparedness of today's students to continue our nation's economic strength well into the 21st century.

- 40 percent of fourth-graders do not read at even a basic level.
- Almost half of the students from urban school districts fail to graduate on time, if at all.
- Average National Assessment of Educational Progress (NAEP) scores among 17-year-olds are lower than they were in 1984, a year after *A Nation at Risk* was released.
- U.S. 12th graders only outperformed two out of 21 nations in mathematics.
- American students fall farther behind students from other countries the longer they are in school.
- Public institutions of higher education annually spend $1 billion on remedial education.

The NCTM (National Council of Teachers of Mathematics) was the first organization to seriously face this educational crisis with its 1989 ground-breaking document, *Curriculum and Evaluation Standards for School Mathematics*. This document was revolutionary in its attempt to bring about change in the way mathematics was then being taught in schools. Throughout the following decade, the NCTM continued to refine and update its original *Standards*...with subsequent *Standards* documents that dealt with distinct topics of educational importance. The *Professional Standards for teaching Mathematics*, 1991 and the *Assessment Standards for School Mathematics* in 1995, challenged the assumption that mathematics is only for a select elite with the compelling contention that *everyone* needs to understand mathematics. In addition, the NCTM documents also maintained the notion that equity and excellence should not be in conflict. The NCTM's most recent publication, the *Principles and Standards for School Mathematics*, is an updated compilation of the three previous documents.

What makes this new document different from its predecessors is that while it retains the underlying philosophical paradigm shift presented in the original *Standards*, it also includes the addition of six foundation principles upon which the standards rest. The goals outlined in the original *Standards*, increased attention towards: problem solving, mathematics communication, reasoning and higher order thinking skills, as well as creating quality mathematics education for all students still remain. The additional instruction and assessment guidelines added, deal with the manner in which mathematical learning occurs, as well as the integration of technology and computers within the curriculum.

The NCTM's six central **Principles** (basic tenants that underlie the assumptions made about a high-quality mathematics program) that form the foundation for its ten Standards include:

- **Equity**: mathematical learning for all students
- **Mathematics Curriculum**: curriculum emphasizing "meaningful" mathematics taught through coherent and comprehensive curricula
- **Teaching**: referring to the competent and caring teachers who work towards the goal of having all students understand and be able to use mathematics
- **Learning**: establishing programs that enable all students to understand and use mathematics
- **Assessment**: employing the kind of assessment that informs teaching as well as monitors, enhances and evaluates the learning of all students
- **Technology**: used to enhance understanding in a program that prepares students to use mathematics in an increasingly technological world.

The ten standards identified in the new NCTM document describe two areas of mathematical focus that students should be learning, the areas of content standards and process standards. **Content Standards** refer to the specific mathematics students should know such as:

1. **numbers and operations,**
2. **patterns, functions and algebra**
3. **geometry and spatial sense**
4. **measurement**
5. **data analysis, statistics and probability.**

Process Standards refer to the ways students acquire and use that knowledge. These are:

1. **problem solving**
2. **reasoning and proof**
3. **communication**
4. **connections**
5. **representation**

Current studies and brain research findings reinforce these NCTM recommendations. New brain imaging techniques such as the PET (Positron Emission Tomography) and MRI (Magnetic Resonance Imaging) have led to discoveries as to how the human brain actually functions. Some of these discoveries suggest that many of the instructional methods traditionally popular in the U.S., actually function in direct opposition to the way the brain processes of information. By mistakenly focusing on the memorization of isolated skills and facts rather than inquiry and discovery involving connections and comprehension of underlying concepts, much of American education has been organized for failure. As adults, we create meaning as much from efforts to answer our own questions as from what we read or hear. Learning that is brain-compatible is learning that takes advantage of this innate search for meaning and turns it into an effective teaching methodology that educates through the presentation of problem situations in need of solutions. These problem situations do not have a single "correct answer," but rather ask students to learn through the act of trying to resolve those problems.

In a recent edition of Educational Leadership [1], Wolfe and Brandt highlighted the following key findings about the brain and learning.

1. The brain goes through actual physiological changes as a result of experience. The environment in which a brain operates will determine, to a large degree, the functioning ability of that brain. (The environment affects how genes work, and genes determine how the environment is interpreted).

2. Intelligence is not fixed at birth. Studies have successfully demonstrated that early intervention programs can prevent children from having low IQs or mental retardation.

3. Some abilities are acquired more easily during certain "sensitive" periods, or "windows of opportunity." With PET (Positron Emission Tomography), brain energy use can be visually depicted. Through studies measuring such energy levels at different ages, peak learning periods have been scientifically ascertained.

4. Learning is strongly influenced by emotion. Strong positive emotions will make a learning experience more memorable whereas if the emotion is too strong (threatening) the level of learning will decrease.

The need for a paradigm shift in the way education is viewed in this country has only been accentuated by the February 1998 release of the Third International Mathematics and Science Study (TIMSS)[2]. The key finding from TIMSS being that the mathematics curriculum

[1] Wolfe, P. and R. Brandt. "What do we know from Brain Research?" Educational Leadership. 56.3, 8-13, November 1998.

[2] National Center for Educational Statistics Third International Mathematics and Science Study. Pursuing Excellence: A Study of U.S. Fourth, Eighth, and Twelfth Grade Mathematics and Science Achievement in International Context. Washington, D.C., 1998.

in the United States is neither as advanced nor as challenging as the curriculum in other TIMSS nations. The main reason the U.S. curriculum did not compare well with those of other nations is due to the fact that in the U.S. too many topics are covered in too little depth. In fact, the American mathematics curriculum has been described as a curriculum that may be a mile wide but runs only one inch deep. The focus in mathematics education today should be on the goal of teaching for comprehension, not only the understanding of new concepts but also the application those concepts in new and different situations.

In classrooms that support brain-compatible learning (learning that acknowledges the brain's rules for meaningful learning...and always keeps those rules in mind), students are offered the kinds of learning experiences that teach knowledge organization, information synthesis, reinforcement of self-correction skills, and concept application. These kinds of learning experiences both demonstrate and employ the contextual application of new knowledge in much the same way these applications occur in real life, by infusing the content learning with relevancy and connection to the world outside the classroom. Brain-compatible instruction is the kind of instruction that focuses on solutions to problems requiring reason application rather than the repetitious memorization of bits of information. While all students should be held to rigorous standards, some may, indeed, need to achieve these goals through different and perhaps unconventional ways.

One of the most effective ways of achieving comprehension with the contextual application of new knowledge is through a brain-compatible methodology referred to as performance-based learning. Performance-based learning involves the application of knowledge rather than its memorization and results in a high quality product or performance. It is where assessment and feedback are given during instruction rather than after, and where assessment is based on the learning process as well as the final product. Performance-based instruction is a highly effective methodology because it allows the teacher to continually monitor for student understanding and then adjust the instruction to clarify and/or eliminate potential areas of confusion and misunderstanding.

For a learning environment to be performance-based, it must be a place where the learning is organized through the implementation of performance tasks. Such tasks consist of activities, problems, or projects that require students to demonstrate what they know and can do. They build on earlier content knowledge, process skills, as well as work habits, and are placed in the study unit to enhance learning as the students begin to process and synthesize the knowledge and experience gained from that unit. By definition, such tasks cannot be added on at the end of instruction, but instead, integrated within the unit to enhance and solidify the learning experience. Performance tasks reinforce brain-compatible learning concepts in that they are designed to function much the way the brain learns new information, by introducing new material in an integrated and comprehensive manner rather than as isolated bits and pieces. It is this integration and comprehensiveness that enables the brain to make faster and easier connections.

The design and development of a good performance task requires six elements to provide a framework for the design, development, and implementation of performance-based learning. These six elements, or '*Pillars'* of performance task design (Ronis, 1999) are:

1. Establish clear performance goals (content standards)
2. Seek to employ 'authentic' tasks and products
3. Teach and emphasize criteria levels and performance standards
4. Provide models and demonstrations of excellence
5. Teach strategies explicitly
6. Use ongoing assessments for feedback and adjustments

1. ESTABLISH CLEAR PERFORMANCE GOALS

All design begins with:

- A clear statement of what is to result (the intended achievement as well as how it will be assessed).
- The goals or content standards to be assessed (the critical and essential outcomes to be evaluated).
- The identification of observable and meaningful indicators for each of the standards (how students will demonstrate what they know and can do well in order to prove that they understand).

In the establishment of performance goals or targets, two main ideas must be kept in mind. These goals are:

- What is it that we want the students to understand? and
- What is it that can demonstrate to us that they do understand? (What kinds of assessments ask students to apply this new knowledge and/or skills).

To achieve understanding, we must first think of the curriculum in terms of desired 'performances of understanding' (assessments), and then plan backwards so as to focus on the critical and essential knowledge (the knowledge we want our students to remember in the future). Planning backwards simply means organizing the instruction around the content standards and developing assessments that target those content standards. Once the standards (both content and performance standards) have been identified, the choice of assessment evidence can be developed (evidence which demonstrates that the desired learning has been achieved).

In an activity oriented or 'authentic' curriculum, instruction becomes a means to an end. The question, "what instructional purpose will be met by this performance or task?" serves as a guide for the development of that task.

2. EMPLOY 'AUTHENTIC' TASKS AND PRODUCTS

- Create a meaningful context for the performance task based upon real problems and/or student interests.

The term 'authentic' refers to real world application(s) of knowledge and skills, as well as connections to student experiences and interests. It is this 'authenticity' that helps students see the connections between school and the real world. These applications that mimic challenges and problems as they occur in the world outside the classroom serve as the 'hook' for engaging students in meaningful and important work.

3. TEACH AND EMPHASIZE CRITERIA LEVELS AND PERFORMANCE STANDARDS

- Identify the thinking skills/thought processes that will encourage the thoughtful application of knowledge and skills.

The manner in which the project or task will be assessed as well as the standards that will be used to assess it must be clearly explained to the students before that unit is started. It is best when both teachers and students agree on the criteria for standards and evaluation. There should be no mystery or guess work on the student's part as to what the basis for the grade will be.

The best way to achieve this criteria consensus is by establishing a rubric (scoring tool) specifically for the task evaluation. The project rubric contains the criteria that categorize the different levels of quality, understanding, or proficiency to be used in the assessment. Knowledge of the rubric does not automatically appear in the minds of the students. They must be carefully instructed with regard to the rubric's elements in order to avoid any misunderstanding and so that the resulting project grade is not a surprise.

It is easier for students to gain understanding of a rubric if they take part in its design. In fact, it is through such rubric design that students develop a thorough understanding of what the criteria are as well as how those criteria will be used in the assessment.

4. PROVIDE MODELS AND DEMONSTRATIONS OF EXCELLENCE

- A Benchmark is a standard for evaluating a performance or a product
- Benchmarks, used as exemplars (models), demonstrate student work and achievement that highlight characteristics on the different levels of the rubric performance scale.
- Identify the student product/performance which will provide evidence of attainment of the outcomes/standards (what will be used to provide evidence of understanding).

Explaining the rubric is not enough for comprehension of the different rubric levels. Students must be shown exactly what the different benchmarks (rubric levels) look like. They need to see tangible sample student work at each of the rubric levels to completely grasp the concepts, internalize those concepts, and as a result, be able to evaluate their own work in an informed manner. The ability to critique one's own work is prerequisite for becoming a lifelong learner.

5. TEACH STRATEGIES EXPLICITLY

Competencies and strategies must be explicitly taught if performance improvement is to be achieved. Some possible strategies might include:

- problem-solving heuristics (instructive methods that aid learning through exploration)
- self-moderating strategies
- thinking skills processes
- mnemonic techniques (techniques that promote learning because they serve as cueing structures to facilitate recall i.e. acronyms, rhyming, sequence linking)
- study skills
- organizational strategies

These strategies are all very teachable, and will translate into improved performance results. Good strategy instruction includes information about not only what a particular technique is, but how and when to use it.

6. USE ON-GOING ASSESSMENTS FOR FEEDBACK AND ADJUSTMENTS

From: teach ⟶ test/grade ⟶ move on

To: teach ⟶ assess ⟶ adjust ⟶ assess

Quality is best achieved through consistent, incremental improvement. This refers to the practice of giving regular assessments throughout the unit, followed by necessary instructional adjustments based on the information gained from those assessments. Deeper levels of understanding and higher levels of proficiency are achieved only as a result of trial, practice, adjustments based on feedback, and more practice.

Performance-based instruction underscores the importance of using on-going assessment to provide guidance for improvement throughout the learning process. The traditional method of waiting until a unit has been completed and then assessing that unit with a separate, unrelated activity called a TEST, does not help in the adjustment or the modification of instruction when it is most needed, during the learning process itself.

In conclusion, then, the NCTM *Principles and Standards* provide educators with an effective framework for the kind of mathematics instruction that will prepare our students for the 21st century. These *Principles and Standards* along with brain-compatible and performance-based learning form the components essential to the weaving of that tapestry we call effective education.

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