Demystifying the Equations of Sedimentary Geology

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Description

One of the great challenges in teaching undergraduates is finding ways to get them to apply knowledge or skills learned in one class to problems encountered in subsequent classes. Case in point: the use of algebra, trig, and even rudimentary calculus in geology classes! This activity suggests three practical ways instructors can build students' confidence in their ability to peer into the meaning of the equations they encounter in sedimentary geology. These techniques are:

(1) Surgical Strike Reviews – 5 to 10-minute targeted review of relevant math principles at the beginning of the appropriate lecture;

(2) Unit Analyses – assigning fundamental units of Mass, Length, and Time to test whether an equation has been derived correctly or to explore the meaning of derivative units of measure that may be unfamiliar to students; and

(3) Perturbation Interrogation – asking students to identify whether the quantity of interest described by an equation will increase or decrease when individual components of the equation increase or decrease.

Context

These techniques are easily adaptable for application in most undergraduate courses in geology. The examples included in this exercise were drawn from a required undergraduate course in sedimentation and stratigraphy. They assume a basic working knowledge (high school or first-year college level) of algebra, geometry, trigonometry, physics, and chemistry.

Goals of the Activity

The purpose of these exercises is to reinforce what students already know about equations and the mathematical expression of physical or chemical phenomena.
A secondary goal of these exercises is to enhance students' mathematical reasoning skills (analytical derivation of equations and intuitive understanding of how system variables interrelate) and promote sound scientific work habits (careful use and double checking of proper units).

This activity touches on each of the higher levels of Bloom's taxonomy of educational objectives. Examples include:

- Comprehension - *predict* the impact that changing a system variable will have on an equilibrium relationship.
- Application –*calculate* the value of a specific variable under specified conditions using the appropriate equation.
- Analysis – *analyze* units for an equation or parameter; *explain* why turbulent flow should be expected in streams with higher gradients.
- Synthesis - *rearrange* an equation to solve for a specific variable; *substitute* one equation into another and *reformulate* the resulting equation.
- Evaluation – *assess* the impact of changing a system variable on an equilibrium relationship; *recommend* changes in systems variables to achieve a desired outcome.

Evaluation
I conduct immediate, in-class assessment through the use of example problems on the board and incomplete problems included in lecture notes (to be completed, reviewed, and evaluated during class). Unit Analysis and Perturbation type questions are also considered fair game for exam questions. Students generally respond well to these, having had multiple opportunities to practice their application during class.

Potential Applications for Sedimentary Geology:

Mathematical Concept	Related Course Topic	Surgical Strike	Unit Analysis	Perturbation Interrogation
Sines, cosines, and unit circles	True and apparent bed thickness calculations	√		√
Functions, slopes, and derivatives	gradients	√		
Vectors and vector resolution	Settling velocity	√		
Force, Newton's second law $F = ma$		√	√	√
Shear stress $\tau = \mu \frac{dV}{dy}$	Hydrodynamic forces, Newtonian and non-Newtonian fluids		√	√
Boundary shear stress $\tau_o = \rho g R_h S$	Friction along a stream bed		√	√
Dimensionless Numbers: Reynolds $R_e = UL\rho \frac{1}{\mu}$, Froude $F_r = \frac{U}{\sqrt{gL}}$	Laminar/Turbulent Flow; Flow regime		√	√
Vector analysis, Force balance	Particle Entrainment; Stoke's Law and Settling Velocity	√	√	√
Exponents and logarithms	Grain size, pH	√		
Probability distribution functions – pdfs and cdfs	Grain size distributions	√		
Proportionality constants	Viscosity, Henry's Law	√		√
Equilibrium constants, Solubility products	Mineral dissolution and precipitation	√		√

Supplemental Materials

Included in online submission:

1. Instructor's Notes – contains tips for using each technique.
2. Example Lecture notes
    a. Vectors and coordinates (surgical strike)
    b. Boundary shear stress (unit analysis and perturbation)
    c. Settling velocity – Stoke's Law (unit analysis and perturbation)
    d. Exponents, logarithms, PDFs and CDFs (surgical strike)
    e. Chemical reactions and equilibrium constants (surgical strike and perturbation)