Lesson Title	NTU What? The math behind turbidity.
Length of Lesson	1 days
Created By	Shane A. Irvin
Subject	Geometry, Calculus
Grade Level	$10^{th} – 12^{th}$
State Standards	Solve mathematical situations and application problems involving or using derivatives, including exponential, logarithmic, and trigonometric functions.
DOK Level	DOK 2
DOK Application	Intrigue, Inquiry
National Standards	Use visualization, spatial reasoning, and geometric modeling to solve problems.
Graduate Research Element	Turbidity measurements are an important aspect of my research. To determine if a creek is impaired do to sediment load, it is important to understand the science of turbidity.

Student Learning Goal:

Turbidity is a measure of the cloudiness of water. The higher the turbidity, the harder it is to see through the water. It is a well-studied water quality parameter that helps determine if a water body is impaired and if it requires water treatment.

The learning goal for this lesson is to provide the student with full understanding of the math that is found in scientific tools used in laboratories across the fields of science. This lesson will provide the student with strong mathematic lessons in both geometry and algebra while showing the student with a direct connection of the math they are learning to real world hands on applications.

The teacher's main goal is use the sediment measurement, turbidity, to show the connection of scientific tool and applications to mathematics. While turbidity measurements are electronic requiring little human interaction besides calibration, it is still possible to represent the math that occurs in the light refractions and the conversion of refracted light to Nephelometric Turbidity Units (NTUs). While the equation is difficult and could potentially involve partial differential equations, there is a way to provide the students with basic understanding of the light refraction equation found in turbidity measurements without overcomplicating it.

Once the students fully understand the equation and its variables, the students will form a relationship with the equation by testing water samples of their own.

Materials Needed (supplies, hand-outs, resources):

Writing utencil, clear 3 inch plastic tubes (4 total), tube cap (4 total), secchi or viewing disc (made from thick waterproof paper and permanent marker), metric measuring tape, scissors, notebook paper, instructions on how to make the turbidity measuring equipment, in class assessment.

Lesson Performance Task/Assessment:

Question for open discussion will begin.

What is turbid mean?
So what do you think turbidity means?
What sense do we use to determine turbidity?
Therefore what variable are involved with this measurement?
Why do you think the numbers are the way they are?

Students will study what turbidity is, the math behind turbidity, and construct a turbidity tube to let them see the visuals behind the math. This assessment will allow the students to first hand, see the turbidity outcome numbers in action. Allowing the students to see this activity first hand will provide a better understanding of the math that goes into my research as well as in scientific lab testing.

Letting them make their own turbidity meter will help them find the potential error they create by either not following directions or doing the mathematics on the conversions wrong. This ability to prove error to the students will push them to want to engage even stronger throughout the lesson.

Lesson Relevance to Performance Task and Students:

The lesson plan works in any particular classroom covering mathematic variables, in particular one to two variables. The lesson plan leads the students into inquiry and lets the students push the instructor to tell them what is next. This is blamed on the fact that the students have seen turbid water themselves and may not know the direct cause of it. It is also great for them to connect something they may have seen hundreds of times to the subject they are currently studying, mathematics. This connection take math into the "cool" and "wow" regime, which is sometimes near impossible to complete.

Anticipatory Set/Capture Interest:

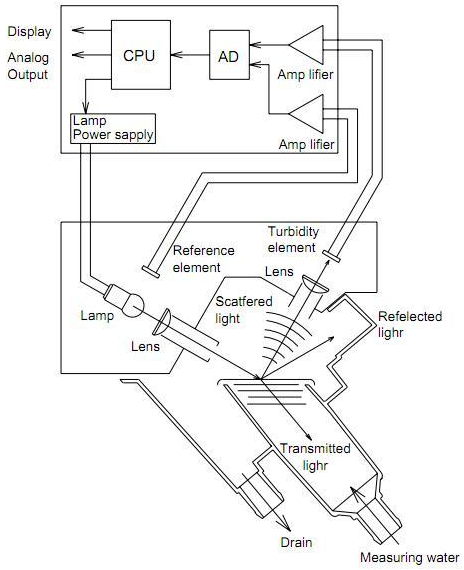
The anticipatory set for this lesson is centered on the reaction to students to why dirty water samples are in their room as well as them knowing they are going to first hand get to explore, in a math class, why the water is dirty. Little do they know the math they are about to learn.

Guided Practice:

Guided practice is up to the teacher and their ability to explain the assets of turbidity.

The teacher will open the lesson with the anticipatory set and present highly turbid water samples to the class asking them questions about the sample (what is it, why is it this way, where have they seen this before). Once the teacher has the students' attention, he/she will explain what turbidity actually is. This will then follow with an open discussion where the teacher asks the students about light refraction and why cloudy water increases it.

Once the students have focused on the lesson, the teacher will then present how turbidity is measured, explaining the next day's chance to make their own turbidity meters. The teacher will explain the basic meter principles:



- Lamp
- Sample
- Scattered light (refracted light)
- Lens
- Turbidity element

Once this is established, the teacher will them start to explain the equation that goes into the turbidity measurements:

$$\tau = \frac{32\pi^3 kT}{\lambda^4}$$ OR $\ln(TSS) = 1.32 \ln(NTU) + C$

τ = turbidity (unknown)
λ = light refracted
k = constant (given) T = constant (given)

where C = around 0
TSS = total suspended solids (given)
NTU = turbidity (unknown)

Once the students have a full understanding of the equation, write examples on the board using the equation but remove some of the variables to see if they can guess. This will get the students using their algebraic skills.

Independent Practice:

Independent practice relies on the teacher's willingness to set up individual stations of samples with already made turbidity tubes or the willingness to allow the students to create their own. If the students create their own (in small groups to prevent a surge of supplies) the lesson can be extended by a day.

The students will follow the guide handed out to step them through the tube making process (reference Myre and Shaw, 2006). The building process will take 30 minutes therefore the lesson can be extended to two days.

Please reference instructions found at Myre and Shaw, 2006.

Remediation and/or Enrichment:

For remediation tutoring and individual attention will be given where needed. The individual IEPs will be supported.

For enrichment, the instructor can go into the depths of the first equation including why the constants are what they are. This involves discussing partial differential equations, only if the students are ready.

Check(s) for Understanding:

Five samples will be presented to the class. Each one, the teacher will allow the students to guess the sample range. Once they are close enough the sample data will be given. The students will then find out the specific variable based off of the equation above on their own paper. Once a few minutes goes by the teacher will ask the students to provide them with answers. These answers should be asked from all students in the class to insure no one is left behind in the task. To finalize, the questions above will be asked again to see if the students can not only link the math to turbidity testing but have a full understanding of turbidity.

The following questions will be re-asked to assure comprehension.

So again, what is turbidity?
What math goes into what we just did?
Where else do you think this science is applied?
Why do you think the numbers are the way they are?
What causes turbidity in our water?

Closure:

The students will be asked what other areas they think this testing could be used in. Once they answers the assessment questions and determine the link between their subject of geometry and water quality applications, the lesson will conclude with one more question for them to ponder on.

Why turbidity units are called NTUs. The teacher should encourage them to find out the history.

Possible Alternate Subject Integrations:

The lesson plan could be incorporated into a physical science or physics light reflection/refraction lesson as well as chemistry to determine the makeup of a chemical using the Beer-Lambert law.

Teacher Notes:

Cost is subjective. Samples can be collected from any location around the school to allow more intrigue.

Myre, Elizabeth and Ryan Shaw (2006). The Turbidity Tube: Simple and Accurate Measurement of Turbidity in the Field. Michigan Technological University.

http://www.cee.mtu.edu/sustainable_engineering/resources/technical/Turbidity-Myre_Shaw.pdf

Murray-Darling Basin Commission (2002). Chapter 4: Turbidity, Conductivity, Light Penetration, and Phytoplankton growth. Australia

http://www2.mdbc.gov.au/__data/page/307/Chapter_04.pdf