PLTW Science Frameworks

PLTW Course: Civil Engineering and Architecture (CEA)

Science Strand being addressed: The Nature of Science and Engineering
Science Sub-strand being addressed: Interactions Among Science, Technology, Engineering, Mathematics, and Society

Science Standard being addressed: 9.1.3.4

Overview:

Science Standard and Benchmarks: 9.1.3.4.2, 9.1.3.4.5

Standard 9.1.3.4: Science, technology, engineering and mathematics rely on each other to enhance knowledge and understanding.

Benchmark 9.1.3.4.2: Determine and use appropriate safety procedures, tools, computers and measurement instruments in science and engineering contexts.

For example: Consideration of chemical and biological hazards in the lab.

Benchmark 9.1.3.4.5: Demonstrate how unit consistency and dimensional analysis can guide the calculation of quantitative solutions and verification of results.

Minnesota Department of Education, 2010

Correlation to AAAS Atlas:

3A/H1*, 3A/H2, 3A/H3b*, 3A/H4**, 9A/H1, 9A/H2*, 9A/H3, 9A/H4, 9B/H3, 12B/H3*, 12B/H4*, 12B/H5, 12B/H6*, 12B/H7, 12B/H9, 12C/H1*, 12C/H3*, 12C/H5**

3. The Nature of Technology

A. Technology and Science

- Technological problems and advances often create a demand for new scientific knowledge, and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research. The very availability of new technology itself often sparks scientific advances. 3A/H1*
- Mathematics, creativity, logic, and originality are all needed to improve technology. 3A/H2
- Technology usually affects society more directly than science does because technology solves practical problems and serves human needs (and also creates new problems and needs). 3A/H3a*
- One way science affects society is by stimulating and satisfying people's curiosity and enlarging or challenging their views of what the world is like. 3A/H3b*
- Engineers use knowledge of science and technology, together with strategies of design, to solve practical problems. Scientific knowledge

provides a means of estimating what the behavior of things will be even before they are made. Moreover, science often suggests new kinds of behavior that had not even been imagined before, and so leads to new technologies. 3A/H4** (SFAA)

9. The Mathematical World

A. Numbers

- Comparison of numbers of very different size can be completed as an approximate by expressing them as nearest powers of ten. 9A/H1
- Numbers can be written with bases other than ten. The simplest base, 2, uses just two symbols (1 and 0, or on and off). 9A/H2*
- When calculations are made with measurements, a small error in the measurements may lead to a large error in the results. 9A/H3
- The effects of uncertainties in measurements on a computed result can be estimated. 9A/H4

B. Symbolic Relationships

- Any mathematical model, graphic or algebraic, is limited in how well it can represent how the world works. The usefulness of a mathematical model for predicting may be limited by uncertainties in measurements, by neglect of some important influences, or by requiring too much computation. 9B/H3

12. Habits of Mind

B. Computation and Estimation

- Use appropriate ratios and proportions, including constant rates, when needed to make calculations for solving real-world problems. 12B/H1*
- Find answers to real-world problems by substituting numerical values in simple algebraic formulas and check the answer by reviewing the steps of the calculation and by judging whether the answer is reasonable. 12B/H2*
- Make up and write out simple algorithms for solving real-world problems that take several steps. 12B/H3*
- Use computer spreadsheet, graphing, and database programs to assist in quantitative analysis of real-world objects and events. 12B/H4*
- Compare data for two groups by representing their averages and spreads graphically. 12B/H5
- When describing and comparing very small and very large quantities, express them using powers-of-ten notation. 12B/H6*
- Trace the source of any large disparity between an estimate and the calculated answer. 12B/H7
- Consider the possible effects of measurement errors on calculations. 12B/H9

C. Manipulation and Observation

- Follow instructions in manuals or seek help from an experienced user to learn how to operate new mechanical or electrical devices. 12C/H1*
- Troubleshoot common mechanical and electrical systems, check for possible causes of malfunction, and decide on that basis whether to fix it themselves or get help from an expert. 12C/H3*
- Develop simple computer databases to store and retrieve information. 12C/H5**

<u>American Association for the Advancement of Science, 2009</u>

Essential Understandings/Big Ideas:

The Civil Engineering and Architecture (CEA) class teaches engineering concepts by using the knowledge of science, technology and math to make them understandable. Science answers the question of why something happens.

For example,: Why does a house get so hot in the summer?
Engineering and Technology answer questions of "how":
How can we cool a house to have the least impact on the environment?

- While Engineering deals with the design aspect of solving a problem, technology is the use of tools and methods to solve the problem.
- Mathematics is used to explain and prove both the why and how questions.

One of the CEA lesson plans that show the interaction of these disciplines is Activity 3.4.3; Soil Testing.

- Site consideration is an important factor when designing a structure because the foundation and grading depend upon the soil characteristics.
- Another consideration of a site is the surface condition and topography that affects the quantity and quality of storm water run-off and is important to consider when planning the placement of driveways, parking spaces and pedestrian access.
- Students test soils to determine the soil properties and, using charts, identify the type of soil.
- Soil is classified according to its grain size and plasticity which impacts the characteristics the soil will exhibit.
- Once the type of soil is known, decisions regarding the load bearing capacity can be made.

What should students know and be able to do [at a mastery level] related to these benchmarks?

- Analyze a site soil sample to determine the Unified Soil Classification System designation and predict soil characteristics important to the design and construction of a building on the site.
- Calculate the percentage of different types of soil within a sample.
- Estimate the increase in storm water runoff from a site.
- Apply Low Impact Development techniques to a commercial site design to reduce the impact of development on storm water runoff quantity and quality.
- Describe factors that should be considered when designing a site and explain their impact on the environment.

Misconceptions:

Student Misconceptions

- Technology is synonymous with computers.
- Soil is just dirt.
- Parking lots don't have an impact on the environment.
- A structure can be built on any land that is available.

- The concern for keeping wetlands available for plants and wildlife is a rural problem.

Teacher Resources:

Teacher Notes

Students will explore and gain an understanding of:

Where does this fit?
Site consideration and soil testing is taught after loads, footings and structural analysis. Students know how to design a building and now begin looking at where to place the structure and the impact it has on the environment.

How is it best to introduce the concept?

- Discuss land properties and where students would like to place their Habitat Home or Commercial Design project. Is the only consideration location, location, location as they say in real estate?
- Use Google Earth to look at vacant properties in the area – point out the surface conditions, elevations and topography of various sites
- Remind them that when they were studying loads and footings, they calculated the necessary soil bearing capacity for various loads and footing sizes. Now they will be testing the soil to determine the different levels of load bearing capacity for different types of soil.
- Have the class do Activity 3.4.4 a web soil survey operated by the USDA Natural Resources Conservation. The survey provides online access to soil data, maps, and information for more that ninety-five percent of the nations counties.
- An instructor might want to collect soil samples from various parts of the country, so that each group of students will get different results.

What do students struggle with the most?
While recording the weights of the different soils as the students are performing the tests, students realize that they are just analyzing a small portion of their original sample. They are repeatedly adding and pouring out water in the Mason jar to separate the fine sand from silt and clay. Once students get the fraction of fine sand in the small sample, they need help realizing that they can apply that same fraction to the original sample.

When calculating storm water run-off between pre-development and post-development, students get confused when the property has multiple types of land that have to be taken into consideration. Teachers can do the example problem, demonstrating the way the curriculum solves the problem by finding a coefficient factor that takes the different land types into consideration. Teachers can also show students that they can do each land type separately and then add them to find the final total. Although it takes more calculations, most students prefer this method.

New Vocabulary

Angle of Repose: The maximum angle of a stable slope of a granular material determined by friction, cohesion, and the shapes of the soil particles.

Design Storm: A selected storm event, described in terms of the probability of occurring once within a given number of years, for which drainage or flood control improvements are designed and built.

Liquid Limit: The minimum moisture content, expressed as a percentage of the oven dry soil weight, at which the soil will begin to flow when subjected to a small shearing force. The liquid limit is determined using a standard liquid limit device.

Low Impact Development: A storm water management approach that uses green space, native landscaping, and techniques that mimic a site's pre-development water cycle.

Plastic Limit: The minimum moisture content at which the soil can be rolled into a thread one-eighth of an inch in diameter without crumbling, determined by trial and error.

Runoff Coefficient: A number that indicates the portion of rainwater that will be discharged by a particular surface.

Vignette:

Students will have completed several building designs using the REVIT software.
The instructor can discuss site considerations for these buildings by using Google Earth to look at vacant lots in the area.
The instructor will point out surface conditions, elevations and topography of the sites chosen.
The instructor asks students "Does it matter what type of soil a structure is built on?"
The instructor reviews loads, footings and foundations and tells the students that different types of soils have different load bearing capacities.
The instructor presents the PLTW Soil Investigation PowerPoint while students take notes in their journal.
The assignment 3.4.4 Web Soil Survey is given for students to research soil using the USDA National Cooperative Soil Survey web site.
Students work in groups of two to find answers to the web search.

The following day, the instructor will have the equipment ready for students to perform soil testing on soil taken from different parts of the state or nation.
Students will work in groups of 4-5 to follow the soil testing directions using Activity 3.4.3.
At the end of the analysis, students will have broken down the original soil into Gravel, course Sand and fine Sand. The silt and clay will have been separated in the water and poured out.
Students record the weights of the soil types and find the percentage of each type.
Students take a sample of the fine Sand, Silt and Clay, add water and make a "cookie" – they then test for dilatancy and toughness. They make another "cookie" and let it dry out so they can test for strength.
Students use the USCS Classification Chart to determine the soil type of their sample.
Once the type of soil is known, students can use the Allowable Soil Bearing Capacities to see what load capacities different types of soil can hold.
Students will use this information to choose a foundation and determine the footing size of their structures.

The instructor checks the students testing results and clarifies concepts as necessary. This leads a discussion about how development changes the characteristics of a site, specifically talking about storm water runoff.
Students ask: "What information is important to consider when planning the placement of driveways or parking spaces?"
The instructor will give a personal example of how they encountered a "flood" condition whether it was stepping in a puddle or the Red River Valley floods where people had to leave their homes in boats due to high water.
The instructor hands out Activity 3.4.5 Storm Water Management and talks about how development affects rainfall runoff.
After students complete the activity, the instructor presents the PLTW Low Impact Development PowerPoint.
The class discusses how they can add LID strategies (rain gardens, green roofs, vegetated swales, rain barrels, permeable pavers and permeable pavement) to their designs to lessen environmental impact of development.

Additional Instructional Resources

Sowers, G.F. (1979). *Introductory soil mechanics and foundations: geotechnical engineering*. New York, NY: Macmillan Publishing.

Lindeburg, M. R. (1994). *Civil engineering reference manual (9th ed.)*. Belmont, CA: Professional Publications, Inc.

Guthrie, P. (2003). *Architects portable handbook: First step rules of thumb for building design*. NY: McGraw-Hill.

Matteson, D, Kennedy, D. & Baur, S. (2010). *Civil engineering and architecture: an introduction.* New York: Delmar Cengage Learning.

Websites:

http://www.glorecords.blm.gov/ Bureau of Land Management – General Land Office. *The official federal land records site.*

http://websoilsurvey.nrcs.usda.gov Soil information for 95% of nation's counties

http://www.hydro.unr.edu/homepages/benson/classes/hydro/uscs.html Unified Soil Classificaiton

Google Earth – property topography, surface condition and elevation

Assessment:

Assessment Methods

1. Which of the following site characteristics will result in the largest rainfall run-off discharge?

A. Sandy bare soil, steep slopes
B. Clay lawn, steep slopes
C. Clay lawn, flat slopes
D. Grassy playground

2. "V-shaped" contour lines on a topographic map indicate which of the following?

A. Steep slopes
B. Roadways
C. A gully or stream
D. A small hill

3. Why is it important to know a site's soil characteristics?

A. Topographic surveying
B. Septic system selection and design
C. Variability analysis
D. Public water supply calculations

4. A soil test was performed on a sample taken from a proposed construction site. The soil was found to consist of 5% gravel, 30% sand, and 65% silt and clay. The "cookie" was extremely difficult to break and broke cleanly.

Which of the following best describes the soil type?

A. Clayey SILT
B. Mud with sand and gravel
C. Sandy CLAY
D. Poorly graded SAND

5. Which site would generate the most runoff from a given rainfall?

A. Flat, sandy beach
B. Sloping, sandy soil
C. Sloping, clayey soil
D. Flat, clayey field

6. Which of the following will occur if a developer places a grass athletic field on land that was previously an asphalt parking lot?

A. Rainfall will decrease
B. Runoff will remain the same.
C. Runoff will decrease
D. Runoff will increase

7. Circle which watershed characteristic will result in greater runoff from rainfall events.

Clay	OR	Sandy soil
Natural meadow	OR	Grass parking lot
7% slope	OR	0.10 ft/ft slope
Shopping mall	OR	Suburban neighborhood

8. Your client has purchased a 10-acre abandoned mall parking lot in western New York, for development of a subdivision of single-family houses. The soil on this flat property is a well-

drained, sandy loam. Estimate the runo-ff (cfs) under pre- and post-development (re-development) site conditions for the 10-year, 24-hour rainfall.

Solution:
Pre-Development
(10 yr Intensity Map and Rational Coefficient from CEA curriculum)
Q = CiA
Q= runoff; C=coefficient of land type; i=rainfall intensity; A=amount of land in acres
From Rational Coefficient chart Mall Parking lot C=0.7 (asphalt ranges could be 0.7 to 0.95)
From 10 yr, 24 hour Intensity Map, Western New York i=3.5
A=10 acres
Q = (0.7)(3.5)(10) = 24.5 cfs (answer can vary depending upon Coefficient used)

Post-Development
Q = CiA
From Rational Coefficient chart Single Family Homes C= 0.4 (ranges could be 0.3 to 0.5)
i = 3.5
A = 10 acres
Q = (0.4)(3.5)(10) = 14.0 cfs (answer can vary depending upon Coefficient used)

So storm water run-off decreased by 10.5 cfs

9. List 5 items or issues to discuss, when presenting a development option to a landowner:

- ________________________________ (Possible answers include:)
- ________________________________ Budget, Materials, Site Grading,
- ________________________________ Ingress/Egress, Environmental effects,
- ________________________________ Time frame for construction, floor plan
- ________________________________ Traffic patterns

10. A soil sample has been collected at a site and analyzed in the lab.

Determine the percent of gravel, med-coarse sand, fine sand, total sand, and silt and clay in the site soil based on the results of the soil lab analysis. Note that all the soil collected in the pan is placed in the Mason jar.

Item	Weight, grams
No 4 sieve	221.6
No 40 sieve	200.3
Bottom Pan	290.5
Mason Jar	188.0

Item	Weight, grams	Soil Sample weight, grams
No 4 sieve and retained soil	241.6	
GRAVEL		
No 40 sieve and retained soil	365.2	
Med. and coarse SAND		
Bottom pan and soil	412.0	
Fine SAND, SILT and CLAY		

Item	Weight, grams	Fraction in mason jar	Soil Sample weight, grams
Mason jar and soil	263.9		
Mason jar and fine SAND	233.4		
Soil in mason jar			
Fine SAND in mason jar			
SILT and CLAY in mason jar			
Fine SAND in pan			
SILT and CLAY in pan			

Presentation of Results		
Item	Soil Sample weight, grams	Percent in soil sample
GRAVEL		
Medium and course SAND		Total SAND %
Fine SAND		
SILT and CLAY		

Solution:

Table 1:

Wt of Gravel = Sieve wt with soil – Sieve wt = 241.6 – 221.6 = 20.0 g

Wt of Med and Course Sand = 365.2 – 200.3 = 164.9 g

Wt of Fine Sand, Silt and Clay = 412.0 – 290.5 = 121.5 g

Table 2:

Soil in Mason Jar = 263.9 – 188.0 = 75.9 g

Fine Sand in Mason Jar = 233.4 – 188.0 = 45.4 g Fraction 45.4/75.9 = .60

Silt and Clay in Mason Jar = 75.9 – 45.4 = 30.5 g Fraction 30.5/75.9 = .40

Fine Sand in Pan = .60 * 121.5 (from Table 1) = 72.9 g

Silt and Clay in Pan = .40 * 121.5 (from Table 1) = 48.6 g

Presentation of Results:

Gravel	20.0 g	20.0/306.4 = .065 * 100 = 6.5 %
Med & Course Sand	164.9 g	(164.9 + 72.9)/306.4 = .776 * 100 = 77.6 %
Fine Sand	72.9 g	
Silt and Clay	48.6 g	48.6/306.4 = .159 * 100 = 15.9 %

Differentiation:

Gifted and Talented
Since soil testing is a group activity involving a lab process, most groups finish about the same time. Gifted students could research which types of soil would make the best foundations for various building types – such as skyscrapers, stadiums or small cabins

Special Education
By having students work in small groups all students can participate in the soil testing activity. The instructor should be helping groups of students by giving clues to the next steps to be taken. Discussions with a student's case manager would be helpful to determine whether any assignment modifications need to be made.

English Language Learners
Use visual diagrams and graphs to explain how to follow the soil testing instructions. Discuss with the school's reading coaches strategies that can be implemented within the classroom to help ELL students. Some examples might be a Word Wall, rewriting some of the PLTW PowerPoints, adding graphics to the PLTW PowerPoints and encouraging students to ask questions when they don't understand a concept. When introducing terms, the teacher should share a story or personal connection to the term. Have students do a vocabulary activity that will give meaning and examples of use to new words. Model the "Frayer Model" for new vocabulary and introduce no more than 8 new terms for a lesson. To check for understanding, teachers can have students answer an "exit slip" question the last 3 minutes of class. Teachers should review notes in student notebooks weekly.

Parents and Administration:

Administrative/Peer Classroom Observation

Students Are:	**Teachers Are:**
Shaking sieves to separate the different grains of soil	Moving around the lab area, helping students follow the written instructions
Weighing and recording soil samples	Clarifying that results from a small sample can be extrapolated to a larger quantity
Using charts to determine the soil type	Explaining how to read the charts

Performing a dry strength, dilatancy, and toughness tests on a small soil specimen	Making sure the lab equipment needed is available to students
Calculating quantities and percentages of the different soil types	Making sure that students don't pour water used in the soil testing (i.e. mud) down the drain.

Professional Learning Communities:

Reflection – PLTW teachers should talk to the Science instructors about what they present in class concerning society's impact on the environment. PLTW and science teachers can re-enforce each other's curriculum to make a bigger impact on the students.

Materials – PLTW teachers can share the above additional instructional resources with other instructors to discuss.

Parent Resources:

Refer parents to the above Additional Instructional Resources.
Encourage parents to discuss how the environment is impacted by society.
Discuss with students any experience they have encountered with flooding either in the home or regional area.
Parents can tell stories about how new technology has changed their life style and those around them.

References:

American Association for the Advancement of Science. (2009). *Benchmarks Online.* Retrieved July 1, 2011, from AAAS-Project 2061: **http://www.project2061.org/publications/bsl/online/index.php**

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