PLTW Science Frameworks

PLTW Course: Principles of Engineering

Science Strand being addressed: The Nature of Science and Engineering
Science Sub-strand being addressed: The Practice of Science

Science Standard being addressed: 9.1.2 .2

Overview:

Science Standard and Benchmarks: 9.1.2.2.2

Standard 9.1.2.2.2: Engineering design is an analytical and creative process of devising a solution to meet a need or solve a specific problem.

Benchmark 9.1.2.2.2: Develop possible solutions to an engineering problem and evaluate them using conceptual, physical and mathematical models to determine the extent to which the solutions meet the design specifications.

For example: Develop a prototype to test the quality, efficiency and productivity of a product.

Correlation to AAAS Atlas:
MN 9.1.2
1A/H1, 1B/H1

National Science Education Standards
Unifying Concepts and Processes Standard K-12:

As a result of activities in grades 9-12, all students should develop understanding and abilities aligned with the following concepts and processes:

- Systems, order, and organization
- Evidence, models, and explanation
- Constancy, change, and measurement
- Evolution and equilibrium
- Form and function

Science as Inquiry Standard B:
As a result of activities in grades 9-12, all students should develop an understanding of motions and forces

Science and Technology Standard E:
As a result of activities in grades 9-12, all students should develop abilities of technological design:

- Understandings about science and technology

Essential Understandings/Big Ideas:

Problems exist everywhere, and they vary in their degree of complexity and importance. Regardless of how problems are identified or from where they come, engineers use the design process to creatively and efficiently solve problems.

One of the ways that engineers design, plan and test structures is through the utilization of statics. Statics is the basis for the study of engineering mechanics and specifically rigid-body mechanics. Statics is concerned with the equilibrium of bodies that are at rest or that move at a constant velocity. Using measurements of geometry and force, Archimedes studied statics concepts in ancient Greece. Most of his work centered on simple machines for construction of buildings.

In this lesson students will:

- Learn how to identify and calculate forces acting on a body when it is in static equilibrium.
- Calculate internal and external forces of a truss.
- Use their knowledge of forces to design, build, and test their own truss designs.
- Design a simple truss bridge utilizing balsa wood, and wood glue for the materials.
- Use an initial design of their choosing.
- Test their design using computer software which calculates the loads on every given member of the structure, both compression and tension.
- Adjust their original design with the information discovered from the computer modeling.
- Trusses will be destructive tested and efficiency comparisons will be made between the weight of the structure and the final weight held.

> 1/2/12 12:31 PM
> **Comment:** This information and that below it seem to be from the statics portion. If the statics portion is being used to reinforce engineering design I think it would work better to rephrase this to focus more on the design aspects of that portion of POE.
> Admin
>
> **Comment from Mike**: I added more information below on the design aspects of the project..

> 1/2/12 1:44 PM
> **Comment:** More focus on this part. Are they looking at choices? Constraints? Performance?
> Admin
>
> Comment from Mike: I added to this section as suggested.

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

- Create free body diagrams of objects, identifying all forces acting on the object.
- Mathematically locate the centroid of structural members.
- Calculate moment of inertia of structural members.
- Differentiate between scalar and vector quantities.
- Identify magnitude, direction, and sense of a vector.
- Calculate the X and Y components given a vector.
- Calculate moment forces given a specified axis.
- Use equations of equilibrium to calculate unknown forces.
- Use the method of joints strategy to determine forces in the members of a statically determinate truss.

> 12/30/11 7:58 PM
> **Comment:** This does reinforce the benchmark of evaluating solutions, but it does not seem to address "develop possible solutions", or the creative aspects.
>
> Mike Sundblad Comments: the Benchmark for 9.1.2.2.2 is: Develop possible solutions to an engineering problem and evaluate them using conceptual, physical and mathematical models to determine the extent to which the solutions meet the design specifications.
>
> In my opinion, the list here includes those things a student should be able to master using a conceptual, physical or mathematical model. Can you master "developing possible solutions?" They can master the concepts on all three different models.
> admin

Misconceptions:

Student Misconceptions

- Students often misunderstand free body diagrams and that each arrow on the object represents a force.
- Students often place the arrowhead in the opposite direction of the direction of force.
- Many students will have efficient designs, but due to irregularities in the construction, such as poor wood joints, excessive glue, or cracked material, the results of their design may show poor efficiency.

Teacher Resources:

Teacher Notes

In this unit students will explore and gain an understanding of:

- Forces acting on a body in static equilibrium
- Calculating internal and external forces of a system
- Basic categories and properties of materials
- Material testing
- Design problems related to materials and structures

Instructors should build a number of truss examples for students to see and touch. The instructor should use one of their own for destructive testing to demonstrate procedures, practice calculations, and design trade-offs such as weight versus cost versus strength.

The instructor should be sure and point out the difference between construction flaws and design flaws when destructive testing.

The concept of movement can be confusing for students. A simple example is shown in the following web example: http://www.gcse.com/fm/moments.html

12/30/11 7:58 PM
Comment: They should also discuss design tradeoffs (weight, cost, strength…). admin

1/4/12 9:00 AM
Comment: There are other misconceptions listed in the science standard relating to engineering design. The third one, at least, could be included here ("cost is the only…").

Mike Sundblad Comments: I don't find in the science standards where the misconceptions relating to engineering design are. I would add any relevant information if I could be pointed to it.
admin

New Vocabulary

Centroid	The geometric center of an area.
Compression Force	A body subjected to a push.
Concurrent Force Systems	A force system where all of the forces are applied at a common point on the body or having their lines of action with a common intersection point.
Cross-Sectional Area	A surface or shape exposed by making a straight cut through something at right angles to the axis.

Direction	The direction of a vector is defined by the angle between a reference axis and the arrow’s line of direction.
Fixed Support	A support that prevents translation and rotation in a beam.
Free Body Diagram	A diagram used to isolate a body from its environment, showing all external forces acting upon it.
Joint	The connection points of members of a truss.
Magnitude	The absolute value of a number.
Member	Slender straight pieces of a truss connected by joints.
Moment	The turning effect of a force about a point equal to the magnitude of the force times the perpendicular distance from the point to the line of action from the force.
Moment of Inertia	A mathematical property of a cross section that is concerned with a surface area and how that area is distributed about a centroidal axis.
Newton’s First Law	Every body or particle continues at a state of rest or uniform motion in a straight line, unless it is compelled to change that state by forces acting upon it.
Newton’s Second Law	The change of motion of the body is proportional to the net force imposed on the body and is in the direction of the net force.
Newton’s Third Law	If one body exerts a force on a second body, then the second body exerts a force on the first body which is equal in magnitude, opposite in direction, and collinear.
Pinned Support	A support that prevents translation in any direction.
Resultant Force	The resultant of a system of force is the vector sum of all forces.
Roller Support	A support that only prevents a beam from translating in one direction.
Scalar	A physical quantity that has magnitude only.
Sense	The sense of a vector is the direction of the vector relative to its path and indicated by the location of the arrow.
Simple Truss	A truss composed of triangles, which will retain its shape even when removed from supports.
Static Equilibrium	A condition where there are no net external forces acting upon a particle or rigid body and the body remains at rest or continues at a constant velocity.

Statically Indeterminate	A structure or body that is over-constrained such that there are more unknown supports than there are equations of static equilibrium.
Structure	Something made up of interdependent parts in a definite pattern of organization, such as trusses, frames, or machines.
Tension Force	A body subjected to a pull.
Vector Quantity	A quantity that has both a magnitude and direction.

Vignette:

Project 2.1.8 Truss Design:

Students will:

- Work in teams of two or three to design trusses as outlined in the activity.
- Be prepared for calculating the centroid of an object, moment of inertia, and forces acting on an object.
- Use the formulas to calculate the forces that would be acting on their own truss bridge design if a prescribed load were placed on the deck.
- Possibly ask to use other materials such as paper, string or cardboard to construct their bridge truss. The instructor should remind these students that engineers work within certain constraints such as materials used or cost of materials.

After students have an initial truss design, they will use a weight of 180 kN for a center load on the bridge deck. This is the same load used in the West Point Bridge Builder software program. It will be assumed there is no horizontal loading of the truss only the vertical load of 180 kN will be used.

> Students calculate the forces in the “X” and “Y” directions from the pin point and rolling point. Using trigonometric functions, the calculated forces are noted on each member. The instructor must remind the students to properly label each force as kilo Newtons (kN). Compressive forces are labeled in red, while tension forces are labeled in blue. This will coincide with the color uses in the Bridge Builder program.
>
> A student may ask, “But doesn’t the load on the pin point and roller points change as the truck drives from one end of the bridge towards the other?”
> The teacher responds, “That is correct. That is a moving load or a dynamic load. We are dealing with statics in this activity, where the loads and the reaction forces are in equilibrium.”
>
> It can be pointed out that the forces can be calculated with the load at any point on the truss. In this example the load is in the center.

Students continue determining the forces exerted by each truss member. When completed students can recreate the truss design using West Point Bridge Builder and check the accuracy of their calculations.

Additional Instructional Resources

Principles of Engineering, 1st Edition, Brett Handley - Wheatfield-Chili Middle School/High School, New York, Craig Coon, David M. Marshal, ISBN-10: 1435428366 ISBN-13: 9781435428362.

The Physics Classroom, http://www.physicsclassroom.com/

Assessment:

Assessment Methods

Explanation

- Students will explain the importance of free body diagrams.
- Students will explain how loads are transmitted through a structure.
- Students will explain how to calculate internal and external reaction forces relating to a structure.

Interpretation

- Students will write journal entries reflecting on their learning and experiences.
- An example of a writing prompt is: What is something you learned today about structures, mathematics, or forces that you did not understand or know before?

Application

- Students will apply their knowledge of statics to calculate the internal and external forces acting on a system.
- Students will create a truss system to withstand design requirements.

Perspective

- At the conclusion of the lesson, students will reflect on what they would have done differently if the truss design project were to be repeated.

Empathy

- Students will describe the experience a structural member undergoes as loads are applied and removed from the member.

Self-knowledge

- Students will reflect on their work by recording their thoughts and ideas in journals.
- Students may use self-assessments as a basis for improvement.

Ideas and questions students may pose and respond to in their journals are:

- Today the hardest concept for me to understand was . . .
- When I work in a group, I find that . . .
- When I work by myself, I find that . . .
- What did I accomplish today?
- Now that I have completed this task, what is next?

Differentiation:

12/30/11 7:58 PM

Comment: POE also makes use of the West Point Bridge program. This is an excellent tool for students to start exploring design options.

Mike Sundblad comment: POE does indeed use West point bridge builder which is used for exploring design options by students. However, all students perform this, so I didn't see this as a means of differentiation for any of these groups- They all design a number of bridges using this software.
admin

Gifted and Talented
Students who understand the concepts could extend their learning through research, design and testing of a two-sided truss bridge. The bridge could be designed upon the basic concepts learned but would include new factors such as racking and roadbed design.

Special Education
For students on an IEP; all PowerPoints, reading materials and activity sheets can be made available on a school sponsored, secure web site. Teachers using interactive whiteboards and other enhancements could make lessons available on a website. Students could review work outside of class time to reinforce their understanding.

The text, Principles of Engineering, Handley, Coon, Marshall; may be purchased for use by students both in and out of class as a resource.

English Language Learners
Vocabulary should be an integral part of the unit. The instructor can use several different strategies to introduce terminology such as a word of the day with weekly and unit quizzes to reinforce learning.

Parents and Administration:

Administrative/Peer Classroom Observation

Students Are:	Teachers Are:
Using the Centroid lesson to determine the centroid of a basic structural shape.	Assisting students in mathematically, scientifically and technologically determining the centroid of structural shapes
Testing beam deflection and comparing answers with Modulus	Demonstrating the beam deflection activity and guiding students in calculating modulus of

of elasticity data.	elasticity.
Able to calculate force vectors given the necessary inputs and angles.	Demonstrating force vectors from practical examples.
Combine the knowledge garnered to determine forces of each member of a truss.	Guide students in calculations to determine truss member forces for a given truss.

Professional Learning Communities

Reflection – Critical questions regarding the teaching and learning of these benchmarks:

- Why is it crucial for designers and engineers to construct accurate free body diagrams of the parts and structures that they design?
- Why must designers and engineers calculate forces acting on bodies and structures?
- When solving truss forces, why is it important to know that the structure is statically determinate?

Materials – suggest articles and books for book study with PLC

Principles of Engineering, 1st Edition, Brett Handley - Wheatfield-Chili Middle School/High School, New York, Craig Coon, David M. Marshal, ISBN-10: 1435428366 ISBN-13: 9781435428362.

Parent Resources:

1/2/12 12:29 PM

Comment: Again, if this outcome if for DESIGN, then there should be some resources related to the design process. “Engineering by Design” by Voland is a college level text but it is FILLED with case studies that high school students might find interesting.

Mike Sundblad comment: I am sure there are hundreds of resources that could be added in this section. I was not aware of this resource but will add it.
admin

Allen, James H. PhD. (2010) Statics For Dummies, http://www.dummies.com/how-to/content/statics-for-dummies-cheat-sheet.html#ixzz1S8xDDejg..

Basic Physics: a self-teaching guide, by Karl F. Kuhn - J. Wiley (1996.03.29) - paperback - 301 pages-ISBN 0471134473.

The Physics Classroom, http://www.physicsclassroom.com/.

Physics For Dummies, Steven Holzner - Wiley (2005) paperback, 384 pages, ISBN 0764554336.

Engineering By Design, Gerard Voland , Prentice Hall (2003) paperback, 640 pages, ISBN 0131409190.

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