Engineered Composite Building Products

ND EPSCoR Lesson Plan

Lesson Title: Engineered Composite Building Products

Lesson Overview: Students can use engineering design skills to build a composite material flooring tile that investigates and analyzes data to explain the mathematical relationship between force, mass, and acceleration while determining best material properties for society needs and wants.

Lesson Objectives:
Students will understand how material properties and design can influence impact strength and damage from different valued forces.
Students will use data to explain the mathematical relationship amount force, mass, and acceleration.
Students will analyze the quantitative data to determine best material properties for composite material flooring that accounts for societal need and wants.

NSF Subject Classification: Physical Science and Engineering

National Next Gen Standards:
HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS-ET1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

North Dakota Standards:
HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS-ET1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

Grade or Grade Band: 6 - 12

Time Needed (estimate): 3 hours

Lesson Author: Allie Kollman

Author Bio: Allie Kollman is a high school physical science and biology teacher at Davies High School in Fargo, ND. Kollman is currently a course captain for Physical Science in Fargo Public Schools. Her focus area this past year has been on developing Evidence-Based curriculum and Evidence-Based Grading.

Scientist/K12 Collaborator & University: Dilpreet Bajwa & James Helphrey, North Dakota State University

Scientist Bio/Research: My name is Dilpreet Bajwa, currently working as a professor in mechanical and industrial engineering at Montana State University. My job involves teaching, research and advising students. I teach courses related to material science and engineering. My research is focused on materials (metals, ceramics, plastics and natural fibers) and engineered composite products used in the automotive, construction and packaging applications. It is a very interesting field since you can work with all kind of materials and technologies to design new products. Most of my students will become mechanical engineers and will find jobs related to designing and testing of new machines, manufacturing cars, trucks and other gadgets. They will use their innovative ideas and creativity to invent new machines that can benefit our society. As a child, I grew up on a small farm far away from the city. Since we didn't have access to mechanics, I always liked to fix farm equipment when it was broken. It gave me joy, happiness and a as sense of accomplishment. From childhood I liked science, math and technology. After graduating from high school my curiosity to understand how different materials and technology can be used to design new products led me to college. After finishing my undergraduate degree in Forestry and Natural Resources in India, I got chance to study and do research at University of Illinois, it was a wonderful experience in my life. My research focused on using natural fibers and plastics to design light-weight high-strength composite materials. Some of the experiments were fun as we broke materials to test their strength. In addition, I got the chance to travel and see some cool places in America and make many friends. After I finished my doctorate in Wood Science and Technology, I got my dream job working for a multinational company in Chicago. In 2012, I moved to North Dakota State University as an associate professor, and in 2019 I moved to Montana State University. My current research is focused on designing light-weight carbon fiber composites for the aerospace industry and application of nano sized materials (cellulose) for improving strength and fire resistance properties of bioplastics.

Preparation/Materials

Background knowledge students must have to be successful:
There are three laws of motion. Newton's second law of motion states that the greater the mass of an object, the more force it will take to accelerate the object. Force is defined as a push or a pull on an object. The force of an object depends on the mass and acceleration of an object. The mass is measured in kilograms and is the amount of matter in an object. The acceleration is measured in meters per second squared and is the rate of change of velocity/speed. The equation is force equals mass times acceleration, or F=ma. Newton's second law of motion can be defined as the acceleration of an object as produced by a force is directly proportional to the magnitude of the force, in the same direction as the force, and inversely proportional to the mass of the object (Newton's Laws of Motion).

Essential Terminology:
Engineered Composites-products consisting of a combination of a smaller components to make a structural product designed using engineering methods.

Water Absorption- the amount of water absorbed by a composite material when immersed in water for a period of time.

Veneers- a thin decorative covering of fine wood applied to a coarser material or wood.

Laminates- overlay with a layer of plastic or some other protective material.

Adhesive- a substance able to stick fast to a surface or object.

Impact Strength- the capability of a material to withstand a suddenly applied load or force.

Force- a push or pull.

Mass- amount of matter an object contains.

Acceleration- the rate of change of velocity or speed.

Newton's second law of motion- the acceleration of an object as produced by a force is directly proportional to the magnitude of the force, in the same direction as the force, and inversely proportional to the mass of the object.

Materials needed:

Lesson 1:

- Quick setting glue
- Markers
- Veneer sheets
- Plastic sheets
- Styrofoam sheets
- Cardboard sheets
- Brushes for glue
- Scissors

Lesson 2:

- 2 student designed tiles from each group made in Lesson 1
- 200 g ball or weight
- 400 g ball or weight
- Tape
- Meter stick

Lesson 3:

- 5 types of composite material flooring
- Water
- Buckets, trays, or tubs to put water in to soak samples of flooring
- Sharpies
- Electronic scales per lab group
- Calipers or rulers per lab group

PowerPoint – found as separate attachment

Procedure/Activities

Lesson 1: Design of Composite Floor Tiles (50 min)

1. Introduce the lesson with what engineered composite products are and why are they are important for society and daily lives (PPT Slides 2 – 3).
2. Review the composite materials and types of engineered materials (PPT Slides 5 – 10, 15).
3. Ask students to discuss with shoulder partners where they have engineered materials in their living space and/or school (laminate on the floors, treated wood in walls, non-wood composites in school ceilings, etc.)
4. Ask students to share answers and write them on the board or on poster board in the front of the room.
5. Discuss with students the pros and cons of laminate flooring (PPT Slides 12 - 13). Discuss that laminate is designed from engineered materials to resist scratching, be more durable to dropping objects, and resist more moisture than other materials like hardwood floors. Laminate can have cons like looking visually less appealing or made from harmful and toxic materials like using different adhesives like formaldehyde. On PPT slide 13, highlight that Lumber Liquidators stopped selling Chinese laminates due to the concerns of the higher levels of formaldehyde in their laminate flooring (Bajwa, Dilpreet and James Helphrey).
6. Explain to students that they will design a composite floor tile and test its impact strength. Explain how different material properties and design can influence the hardness and impact strength of a laminated flooring tile. Instructor will demonstrate that in this lesson they will be designing and building the laminate floor tile and in the next lesson they will be testing the design (Bajwa, Dilpreet and James Helphrey).
7. Instructor demonstrates how their designs will be tested by using different loads (weights 200 g and 600 g) being dropped onto their tiles. Instructor tells students that the force will be calculated, and the deflection of the tile will be measured.
8. Instructor tells students to search on the internet for images of the anatomy of laminate flooring to get a better idea of what their design should look like. (Optional: instructor can use the image on PPT Slide 7 to highlight the different layers of a laminate tile like the vinyl core, fiberglass layer, decorative pattern, wear layer, and adhesive top layer.)
9. Instructor highlights the material list with students (print off material lists from the material section of this lesson plan or have them projected on to board in the front of the classroom).
10. Group students into 3 – 4 students and pass out the Engineered Composite Building Investigation Hand out to students.
11. Instructor highlights material list (wood veneer, Styrofoam, plastic sheet, and cardboard). Instructor explains that students will have the freedom to assemble these laminates in any order they think will have the greatest impact strength against different amounts of forces (Cite from pdf).
12. Students complete part 1 of the handout and get it checked with instructor before next lesson.

Lesson 2: Test the Design of Composite Floor Tiles (50 min)

1. Have students split into their assigned groups from Lesson 1. Instructor will hand back cured tiles back to the appropriate groups.
2. (Optional): If students have not been exposed to Newton's 2nd Law of motion or the equation F = m x a,

then instructor can explain these concepts in more detail. Instructor can explain that Newton's 2nd Law of Motion states that acceleration of an object produced by a total applied force is directly related to the magnitude of the force and inversely related to the mass of an object. Directly related means if one variable increase, then the other variable also increases. Inversely related means if one variable increases, then the other variable decreases. The force of an object can be calculated using the equation F = m x a. F is force, m is mass, and a is acceleration. On Earth, all free-falling objects fall at a constant acceleration of 9.8 meters per second squared. In this investigation, acceleration of the falling loads will be 9.8 meters per second squared (Newton's Laws of Motion).

3. Instructor will review procedure from Lesson 2 found on the Engineered Composite Building Investigation handout and can demonstrate lab procedure if needed.
4. Students will do investigation, fill out Data Table 1, and answer follow-up questions from Lesson 2 on the Engineered Composite Building Investigation.
5. (Optional extension for groups who finish their calculations and follow-up questions early): Have students graph the data from the force and deflection then answer the follow-up questions from the Optional section from Lesson 2 on the Engineered Composite Building Investigation handout.

Lesson 3: Evaluating Moisture Properties of Composite Floor Tiles (50 min)

1. (Important Note) This lesson's investigation requires that the instructor to take the initial measurements for students and soak the composite material samples in water for at least 2 hours. To save time for the instructor and have the lesson be completed within the normal class period, the instructor could have students take the initial measurements the day before and leave them to soak overnight.
2. Lead whole group discussion on Lesson 2's results. Have student groups share what layers of materials did better against the different amount forces. Instructor will write results on board or poster board. Instructor explains that the properties of materials matter when designing composite floor tiles to have greater impact strength.
3. Instructor transitions discussion that when designing composite floor tiles that moisture properties also are important. Instructor explains that when designing different flooring, buyers want flooring that will not be ruined by water absorption and breakdown (Bajwa, Dilpreet and James Helphrey).
4. Instructor will review Lesson 3 overview and procedure with students. Instructor will explain that students will test water absorption properties of different composite materials.
5. Instructor will tell students that the initial measurements were already taken of the five different composite material samples and soaked for 2 – 4 hours. Instructor will explain that they will take the final measurements and do the water absorption equations.
6. (Optional): Instructor can review equations with students prior to them performing the investigation. Students will be measuring the water absorption, thickness swelling, and the volumetric change of the composite materials. W represents weight in grams. V represents volume measured by length x width x height in millimeters. The equation for % of water absorption or (WA) = (W2 – W1)/W1 x 100. The equation for % of volumetric change or (VC) = (V2 – V1)/V1 x 100.
7. Instructor will be divided students into the same student groups that students were in from Lesson 1 and 2. Students will read through the directions and perform the investigation filling out the data table and follow-up questions on the Engineered Composite Building Investigation handout.
8. Instructor will go around the room helping where necessary.

Extensions for above average students:

Discuss:

1. What is impulse force and how does it relate to collisions?
2. How does society need and want for strong impact strength floors affect human health when companies use toxic chemicals like formaldehyde to cure flooring?

Watch the following videos for further ideas:

1. **https://www.youtube.com/watch?v=0efXaBr_JcU (Lesson 2)**
2. **https://www.youtube.com/watch?v=kKKM8Y-u7ds&t=74s (Lesson 2)**
3. **https://www.youtube.com/watch?v=FFikbjei6HQ (Lesson 3)**

Websites to explore and research topics:

https://www.scienceprojects.org/impact-force-of-falling-object/ (Lesson 1)

- Investigate why falling objects have a high impact force.

https://www.rapidrestorationmn.com/2019/05/16/how-does-water-affect-different-types-of-flooring/ (Lesson 3)

- How does water affect different types of flooring like tiles, hardwood, laminate, carpet, and vinyl and linoleum?

Mediation/Support for students that need it:

- List the vocab words with definitions on the front board or hand out them listed on a piece of paper for students to reference.

Standards Alignment

ND Science Standard(s):
HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS-ET1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

Disciplinary Core Idea: Physical Science and Engineering & Technology
PS2.A: Forces and Motion

- Newton's second law accurately predicts changes in the motion of macroscopic objects.

ETA.A: Defining and Delimiting Engineering Problems

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

North Dakota DPI Standards:
HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS-ET1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

Next Gen Standards:
HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS-ET1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

Science and Engineering Practices
HS-PS2-1
SEP4: Analyzing and interpreting data

HS-ET1-1:
SEP1: Asking Questions and Defining Problems

Cross Cutting Concepts

HS-PS2-1

Cause and Effect: empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

HS-ET1-1

Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World

Unit Objectives

- Students can use engineering design skills to build a composite material flooring tile that investigates and analyzes data to explain the mathematical relationship between force, mass, and acceleration while determining best material properties for society needs and wants.

Assessment

- Students analyze data to support the claim that Newton's second law has a mathematical relationship between force, mass, and acceleration.
- Students build and test an object while collecting quantitative data that allows them to analyze solutions that account for societal needs and wants of durable and water-resistant flooring.

Daily Plans and Assessments

Learning Target for each day/activity

- Students will understand how material properties and design can influence impact strength and damage from different valued forces (Lesson 1).
- Students will use data to explain the mathematical relationship amount force, mass, and acceleration (Lesson 2).
- Students will analyze the quantitative data to determine best material properties for composite material flooring that accounts for societal need and wants (Lesson 3).

Criteria for Success/Assessment for each activity

- Students analyze data to support the claim that Newton's second law has a mathematical relationship between force, mass, and acceleration (Lesson 2).
- Students build and test an object while collecting quantitative data that allows them to analyze solutions that account for societal needs and wants of durable and water-resistant flooring (Lesson 3).

Additional Lesson Resources / Materials

References:

- "Newton's Laws of Motion." *Rader's Physics4kids.com,* http://www.physics4kids.com/files/motion_laws.html
- Bajwa, Dilpreet and James Helphrey. "Engineered Composite Building Products." 2015. North Dakota State University. Microsoft PowerPoint presentation.
- Bajwa, Dilpreet and James Helphrey. "Nature Sunday Academy Lesson: Engineered Composite Building Products." 2015. PDF File.

Websites for purchasing materials

- Quick setting glue
  - https://www.amazon.com/Gorilla-Wood-Glue-ounce-Bottle/dp/B001E4E3KY/ref=sr_1_26?dchild=1&keywords=quick+setting+glue+for+wood&qid=1597455131&sr=8-26
  - https://www.amazon.com/Titebond-Quick-Thick-Multi-Surface-2-Pack/dp/B00JEKF1AQ/ref=sr_1_8?dchild=1&keywords=quick+setting+glue+for+wood&qid=1597455174&sr=8-8
- Sharpies
  - https://www.amazon.com/Sharpie-1884739-Permanent-Markers-Point/dp/B00G4CJ8GK/ref=sr_1_5?dchild=1&keywords=sharpies&qid=1597455097&sr=8-5
- Veneer sheets
  - https://www.amazon.com/CHERRY-VENEER-Paper-Cardstock-Warehouse/dp/B06XCGZMK6/ref=sr_1_9?dchild=1&keywords=veneer+sheets&qid=1597455016&sr=8-9
  - https://www.amazon.com/Veneer-Variety-Domestic-Fingerboard-Marquetry/dp/B07RDMN7L4/ref=sr_1_8?dchild=1&keywords=veneer+sheets&qid=1597455016&sr=8-8
  - https://www.amazon.com/Premium-Plywood-Perfect-Cutting-Woodpeckers/dp/B078JZG5J2/ref=sr_1_15?dchild=1&keywords=veneer+sheets&qid=1597455584&sr=8-15
- Plastic sheets
  - https://www.amazon.com/Jekkis-Stencil-Templates-Material-Stencils/dp/B07TFJ2KWL/ref=sr_1_33?dchild=1&keywords=plastic+sheets&qid=1597455239&sr=8-33
- Styrofoam sheets
  - https://www.amazon.com/DAT-Cushioning-Material-Supplies-Shipping/dp/B07TRPGJYX/ref=sr_1_8?dchild=1&keywords=styrofoam+sheets&qid=1597455420&sr=8-8
- Cardboard sheets
  - https://www.amazon.com/Juvale-Corrugated-Cardboard-Sheets-Inches/dp/B07TFGJD8S/ref=sr_1_5?crid=6TUFKA0CLSD0&dchild=1&keywords=cardboard+sheets&qid=1597455457&sprefix=cardboard+%2Caps%2C221&sr=8-5
- Brushes for glue
  - https://www.amazon.com/Foam-Paint-Brush-inch-Painting/dp/B07X3GN59P/ref=sr_1_4_sspa?dchild=1&keywords=foam+brushes&qid=1597455484&sr=8-4-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExTVpXQ0pCREk1T1AzJmVuY3J5cHRlZElkPUEwN

Dk5NTExMkI3UFpBSENSUDQ3RyZlbmNyeXB0ZWRBZElkPUEwNjU3ODIzMVE2UUpRTTQ5MTA0TCZ3aWRnZXROYW1lPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=

- Scissors
  - https://www.amazon.com/Scissors-Titanium-Multipurpose-Comfort-Grip-Handles/dp/B07H3QKN2Z/ref=sr_1_7?dchild=1&keywords=scissors&qid=1597455523&sr=8-7

Lesson 2:

- Weights
  - https://www.carolina.com/lab-balances-scales/mass-set-bar-hexagonal-solid-steel-set-of-7/702091C.pr?question=weights
- Tape
  - https://www.amazon.com/Masking-General-Painters-Painting-Labeling/dp/B07YB2L526/ref=sr_1_4_sspa?dchild=1&keywords=masking+tape&qid=1597455968&sr=8-4-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExSUwzU0hXVUswMkRWJmVuY3J5cHRlZElkPUEwMDg0MTIzM081UDhWRlVaN0hSRCZlbmNyeXB0ZWRBZElkPUEwNzU4NDEyMzdGT09aUzdTNjZaSSZ3aWRnZXROYW1lPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=
- Meter stick
  - https://www.amazon.com/ETA-hand2mind-Meterstick-Yardstick-Classroom/dp/B01D9KHONS/ref=sr_1_1_sspa?dchild=1&keywords=meter+sticks&qid=1597455988&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFZWDJHSkk2SEhPNDImZW5jcnlwdGVkSWQ9QTA3MDA4ODNNV0pYQk9WQkVSWVUmZW5jcnlwdGVkQWRJZD1BMDk1MDE5MUlHTUtEQU1VTjVFTyZ3aWRnZXROYW1lPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=

Lesson 3:

- 5 types of composite material flooring
  - Same as lesson 1 materials (wood veneer, plastic sheets, cardboard, styrofoam, plastic sheets)
- Buckets, trays, or tubs to put water in to soak samples of flooring
  - https://www.amazon.com/Idomy-Small-Plastic-Basin-4-Pack/dp/B07HQKN2Z8/ref=sr_1_7?dchild=1&keywords=plastic+tub&qid=1597456126&sr=8-7
- Sharpies
  - https://www.amazon.com/Sharpie-1884739-Permanent-Markers-Point/dp/B00G4CJ8GK/ref=sr_1_5?dchild=1&keywords=sharpies&qid=1597455097&sr=8-5
- Electronic scales per lab group
  - https://www.amazon.com/Digital-Touch-Pocket-Scale-0-01oz/dp/B078SNH83F/ref=sr_1_1_sspa?dchild=1&keywords=electronic+scale&qid=1597456085&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEzNjcyWUo2NzYyQTMmZW5jcnlwdGVkSWQ9QTA5MjU3MjQyU1ZCNjZaNTlLOU5CJmVuY3J5cHRlZEFkSWQ9QTAyNTQ3MDIxWkRSMEJQUFpaQlYzJndpZGdldE5hbWU9c3BfYXRmJmFjdGlvbj1jbGlja1JlZGlyZWN0JmRvTm90TG9nQ2xpY2s9dHJ1ZQ==
- Calipers or rulers per lab group
  - https://www.amazon.com/Safet-T-12-Inch-Rainbow-Plastic-Classroom/dp/B01MT4FRD0/ref=sr_1_5?dchild=1&keywords=rulers&qid=1597456047&sr=8-5
  - https://www.amazon.com/Digital-Caliper-Sangabery-inches-Vernier/dp/B07VSVMWTJ/ref=sr_1_3?crid=1RQ7A6DDIBOWN&dchild=1&keywords=caliper+measuring+tool&qid=1597456066&sprefix=cali%2Caps%2C220&sr=8-3