Into the Outdoors

Educational Partners:

WOOD: A SCIENTIFIC WONDER

High School Lesson – Revolutionary Wood Resources

THE FOREST PRODUCTS LAB

Revolutionary Wood Resources

Developed By: Gina Smith, LEAF – Wisconsin's K-12 Forestry Education Program

Target Grade Level: 9-12

Appropriate for 6-8
Appropriate for 3-5 if educators modify reading resources to their reading level (or substitute with alternate resources)
Suggested resources for K-4 included

Science Categories

Forestry, Properties of Wood, Wood Products, Sustainability

Time Frame: 4–5 class periods

- **Introduction:** 10-35 minutes
- **Activity 1:** 15 minutes
- **Activity 2:** 3 class periods
- **Conclusion:** 20 minutes

Materials

- *The Forest Products Lab* episode or Nanocellulose Classroom video
    - If using the full episode, watch from (21:49 - 23:41) and (23:44 - 25:37) where Emma sneaks into the Advanced Composites labs and show the last few segments on lignin and nanocellulose.
- *The Greener World of Tomorrow: Built with Revolutionary Wood Products*, by Lara Murray and Amy Androff, USDA Forest Service Article (12 October 2021)
    - Allow students to access online or print copies for students
    - https://www.fs.usda.gov/about-agency/features/greener-world-tomorrow-built-revolutionary-wood-products
- Student Sheet: 9-12_Revolutionary Wood Resources_Reading Activity Sheet 1
- Student Sheet: 9-12_Revolutionary Wood Resources_Innovation Activity Sheet 2

Key Words

- cellulose, lignin, nanocellulose, sustainable

Learning Objectives

Students will be able to:

- Describe the characteristics of nanocellulose that make wood a resource with infinite applications for the future.
- Explain how using nanocellulose supports a sustainable future and helps combat climate change.
- Evaluate a commonly used product and propose a nanocellulose-based innovation to enhance its design or performance.

Activity Summary

Students will view an Into the Outdoors episode and read an article from the U.S. Forest Products Laboratory to learn about nanocellulose and its ability to transform products of the future. Students will examine a commonly used product and propose a nanocellulose-based innovation that will enhance its design or performance.

Vocabulary

Cellulose: The main substance found in plant cell walls, cellulose fibers help plants stay stiff and upright; cellulose is made up of a long chain of glucose molecules (glucose is made of carbon, hydrogen and oxygen atoms).
Lignin: Found in plants, especially woody plants like trees; it is like a glue that holds the tree together; it adds strength and stiffness to the plant cell wall and is a barrier to help keep water in and insects and disease out.
Nanocellulose: Natural wood-based material made from breaking down cellulose; lightweight, strong, flexible, tiny, particle (1-100 nanometers in size) often in the form of nanocrystals or nanofibers; can be added to other materials to make them stronger, more flexible, etc.
Sustainable: Using and maintaining resources responsibly, so they can support present and future generations.

Background Information

The reading materials included in this lesson provide a lot of background information. Please be sure to review all reading materials prior to completing this lesson with your students. For additional information about Nanocellulose and Nanotechnology, consider reading the following resources from the U.S. Forest Service Forest Products Lab:

- Nanotechnology – U.S. Forest Service, Forest Products Lab website https://research.fs.usda.gov/fpl/forestproducts/nanotechnology
- Nanotechnology – U.S. Forest Service website https://research.fs.usda.gov/forestproducts/nanotechnology

Learning Procedure

Introduction: Segment from *Wood: A Scientific Wonder*

If you have ample time, show the full video, *Wood: A Scientific Wonder*. If you are pressed for time, start where Emma sneaks into the Advanced Composites labs and show the last few segments on lignin and nanocellulose.

- Discuss the following as a class:
  - What is lignin? (see vocabulary)
  - How is it being studied for use in new products or to improve existing products? (Lignin, which is a common waste product of wood, can be used to make lignin bread, a lightweight, strong, porous material that can be used as insulation. This product could replace Styrofoam insulation that is not biodegradable.)
  - What is nanocellulose? (see vocabulary)
  - How is it being studied for use in new products or to improve existing products? (Scientists are examining how to use nanocellulose to make biobased packaging that could replace single-use plastic packaging for food products. They are also looking at adding nanocellulose materials to papers to make them grease-resistant.)

Activity 1: *The Greener World of Tomorrow: Built with Revolutionary Wood Products*

USDA Forest Service Article

Pass out a copy of *The Greener World of Tomorrow: Built with Revolutionary Wood Products* to each student or provide them with the link to access the article online. It is recommended that you pre-read the article as a whole class to help students become more familiar with the topic and help them understand new vocabulary.

After completing the pre-read, instruct students to read the article a second time (you can have them do this independently or with a partner). As they read the article the second time, tell them they need to record information about the following topics in their notes. (Alternately you can have students use the student sheet provided in the lesson, *Revolutionary Wood Resources_Reading Activity 1*.) Tell them to only use information that they read in the article.

- What is nanocellulose?
- How is nanocellulose produced?
- What are some positive/beneficial characteristics of nanocellulose?
- What are some current/future applications of nanocellulose?
- How does the use of nanocellulose in products help combat climate change?

When all students have had time to finish reading and taking notes, discuss the information as a class.

Activity 2: Product Design or Product Performance Innovation

SETUP

Prior to beginning Activity 2, determine the format students should use to share about their innovation, how much class time they will be provided to work on the project, and if there is an appropriate authentic audience they can present their innovation to.

FORMAT

Consider one of the following options or come up with your own.

- Slideshow (google or PowerPoint) with/without presentation
- Product Report (google docs or word) with/without presentation
- Alternate presentation tool like Prezi, Canva, etc with/without presentation

TIME

A minimum of 2-3 class periods is recommended. Students should have at least one class period to do further research on applications of nanocellulose and examine a current product to determine ways it could be improved using nanocellulose. Students will need at least one class period to compile their work into a slideshow or product report. If students are going to present their work to each other or an audience, a third class period will be needed.

AUDIENCE

Try to provide students with an authentic audience to share their work with. Perhaps students could present their innovations to another class – maybe a technical education class or a panel of volunteers from local businesses. Another option is to have students share their work with students from younger grades or with each other – this could be done in a science fair format where students circle throughout the room to learn about the different products.

INSTRUCTIONS FOR STUDENT ACTIVITY

Ask students to think about products they use frequently in their everyday lives. Tell students to also think about the properties of nanocellulose that they learned about from the video and article (it is strong, lightweight, durable, flexible, biodegradable, can be transparent, can provide a barrier). Tell students that nanocellulose has even more properties than what were shared in the video and article. Tell them that is also absorbent, works in a large variety of temperatures, not harmful to living tissue,

able to bond to many different things and it has a high tensile strength – it can undergo a lot of stress without breaking – its tensile strength is higher than Kevlar or stainless steel. Ask students if they can think of any products – ones they use daily or ones they use less frequently – that they could be improved by using nanocellulose.

Tell students that their job is to select a product that they think could be designed better or perform (work) better and come up with ideas on how nanocellulose could be used to improve the design or performance of the product. Pass Activity 2: Product Design or Product Performance Innovation. Review the goal of the project and the instructions:

GOAL

I can evaluate a commonly used product and propose a nanocellulose-based innovation to enhance its design or performance.

INSTRUCTIONS

1. Select a product that you think could be improved by using nanocellulose. It will be easiest if you select a product you use regularly and are already familiar with.
2. Use/test the product to see what works well and what doesn't work well. Record evidence from your testing. If you are unable to test the product, you can look up reviews of the product and take notes on what reviewers say works well and what doesn't work well with the product. Record evidence from reviews.
3. Research properties and applications of nanocellulose to see if there is research/evidence that supports your idea of how nanocellulose could be used to improve the design or performance of the product. Tell students they can use the recommended resources or search for resources on their own.
4. Think about other benefits that could exist from using nanocellulose in this product. Will it be more sustainable, reusable, recyclable, store carbon?
5. Create a report or presentation to share the product you selected, the positives and negatives of the product (with evidence gathered from your own testing or from reading reviews), the nanocellulose innovation you have developed to solve the problem and the extra benefits that will come with using nanocellulose to improve this product.

If students struggle to come up with ideas, discuss the following products that are used daily that would be easy to test/examine and would also probably be good candidates for using cellulose to improve them:

- Household tissues & Hygiene items (paper towels, toilet paper, diapers, feminine products)
- First aid supplies (Bandages, gauze, medical tapes)
- Protective cases for cell phones, tablets, computers
- Packaging materials (for food and for items shipped from stores/Amazon)

- Tell students to think of other things that they want to be strong, light and durable or have some of the other properties/characteristics of nanocellulose (adsorbent, transparent, flexible)

Discuss the rubric that will be used to assess the project and share the parameters you predetermined for the project with students:

- Format
- Time
- Audience

Give students ample time to work and support them as they work. Encourage them to seek feedback from their peers prior to submitting their work. Remind students that peer feedback should be meaningful. Encourage students to point out something their peer has done well and something that could be improved.

Conclusion: Share Student Work

Have students share their work with each other or the authentic audience you selected.

Extending the Lesson (Next Page)

Extending the Lesson (Optional)

ELEMENTARY SCHOOL RECOMMENDATIONS

There are not too many resources available to engage early elementary (K-3) students in learning about nanocellulose. After watching the video, we recommend using the #forestproud website presentation Wood is the new concrete. https://woodisthenewconcrete.com/

While the text in the video is too complex for students to read and understand, since there is no narration, educators can read the following simplified text along with the video:

Original Text	Modified Text for Teacher to Read Aloud
We need green infrastructure	We need green bridges and buildings made from materials that don't harm the earth – like trees.
Infrastructure that is strong	We need bridges and buildings that are strong.
Infrastructure that is resilient	We need roads, bridges and buildings that last a long time.
Infrastructure that helps reduce greenhouse gas emissions	We need bridges and buildings that don't pollute our air.
By harnessing natural building blocks of trees	We can use trees to build bridges and buildings.
Cellulosic nano-materials can be added to traditional construction methods	The teeniest, tiniest parts of wood can be used in cement and other materials used to build bridges and buildings.
To make strong materials, even stronger	The teeny, tiny parts of wood make the materials stronger.
For both people and the planet	This is good for both people and the planet.
In North America's first nano-cellulose infused concrete bridge in Yreka, California	People added tiny particles of wood to cement to build a bridge in California.
Material strength increased by 20%	This made the bridge stronger.
Making it possible to cut greenhouse gas emissions by 1/3	It also didn't add as much pollution to the air.
We need green infrastructure	We need green bridges and buildings.
To build green infrastructure we need sustainable forests	To build green bridges and buildings we need healthy forests.

For the remaining slides in the presentation, summarize the information as follows:

- **What is Nanocellulose?** Nanocellulose is the teeniest, tiniest part of wood you get when you break wood apart as small as possible. The particles are so tiny we cannot even see them. Scientists have to use a microscope to see them. We can add these tiny pieces of wood to other things (like concrete, metal and plastic) to make them stronger and lighter. And, because they come from trees, they are better for the planet.
- **On microscope slide showing nanocellulose say:** The tiny wood particles are smaller than a human hair. A human hair is over 100 times thicker than the tiny particles!
- **For bold words:** STRONGER = Stronger, LIGHTER = Lighter, SUSTAINABLE = Good for the Earth and will last forever if we take care of them, BETTER = Better
- **About the Project:** This is a picture of the first bridge to ever be built with nanocellulose (tiny pieces of wood) added to the concrete. The nanocellulose made the bridge stronger AND they made less pollution when they built it.
- **#forestproud** = # forest proud
- **#justaddwood** = # just add wood

When you are done discussing the information from the website, ask students what they think we should add nanocellulose (teeny-tiny wood particles).

Student Pages
See additional documents that will need to be included:

- Student Sheet: 9-12_Revolutionary Wood Resources_Reading Activity Sheet 1
- Student Sheet: 9-12_Revolutionary Wood Resources_Innovation Activity Sheet 2

Standards

WISCONSIN STANDARDS FOR SCIENCE

- **SCI.CC6.h** Students model complex and microscopic structures and systems and visualize how their function depends on the shapes, composition, and relationships among their parts. They analyze many complex natural and designed structures and systems to determine how they function. They design structures to serve particular functions by taking into account properties of different materials and how materials can be shaped and used.
- **SCI.PS1.A.h** The fact that matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter.
- **SCI.ETS2.B.h** All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of people and the natural environment.

WISCONSIN STANDARDS FOR ENVIRONMENTAL LITERACY AND SUSTAINABILITY

- **ELS.EX4.A.h** Examine the role of renewable and nonrenewable resources in creating sustainable economies. Analyze how the movement of natural resources through acquisition, production, consumption, and disposal impact sustainability of local, regional, and global systems.

WISCONSIN STANDARDS FOR ENGLISH LANGUAGE ARTS

- **ELA.R.9-12.1** Cite textual evidence that strongly supports an analysis of what the text says explicitly/implicitly and make logical inferences, develop questions for further exploration.
- **ELA.R.9-12.2** Objectively and accurately summarize texts, from a variety of genres, to determine one or more themes or central ideas and analyze its development, including how it emerges and is shaped and refined by specific details.
- **ELA.W.9-12.3** Create writing that utilizes organization: introduce a topic; organize complex ideas, concepts, analysis, information and claims to make important connections and distinctions. Establish and maintain a structure and conventions consistent with the mode of writing. Provide a concluding statement or section that follows from and supports the topic, themes, and experiences presented in the text.
- **ELA.W.9-12.4** Produce clear and coherent writing in which the development, organization and style are culturally sustaining and rhetorically authentic to task, purpose and audience.
- **ELA.W.9-12.7** Conduct short as well as more sustained research projects to answer a question or solve a problem that is rhetorically authentic and culturally sustaining; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating an understanding of the subject under investigation.
- **ELA.W.9-12.8** Gather relevant information from multiple authoritative print and digital, academic and popular sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
- **ELA.W.9-12.9** Draw evidence from literary or informational texts to support analysis, reflection, and research.

Resources

- Listed and linked in lesson and student pages.

Into the Outdoors

Educational Partners:

WOOD: A SCIENTIFIC WONDER

Activity 1 – Reading Activity

The Greener World of Tomorrow: Built with Revolutionary Wood Products

What is nanocellulose?	
How is nanocellulose produced?	
Positive/Beneficial Characteristics of Nanocellulose	**Current/Future Applications of Nanocellulose**
How does the use of nanocellulose in products help combat climate change?	

Into the Outdoors

Educational Partners:

WOOD: A SCIENTIFIC WONDER

Revolutionary Wood Resources

Activity 2: Product Design or Product Performance Innovation

GOAL

I can evaluate a commonly used product and propose a nanocellulose-based innovation to enhance its design or performance.

INSTRUCTIONS

1. Select a product that you think could be improved by using nanocellulose. It will be easiest if you select a product you use regularly and are already familiar with.

2. Use/test the product to see what works well and what doesn't work well. Record evidence from testing. If you are unable to test the product, you can look up reviews of the product and take notes on what reviewers say works well and what doesn't work well with the product. Record evidence from reviews.

3. Research properties and applications of nanocellulose to see if there is research/evidence that supports your idea of how nanocellulose could be used to improve the design or performance of the product. Tell students they can use the recommended resources or search for resources on their own.

4. Think about other benefits that could exist from using nanocellulose in this product. Will it be more sustainable, reusable, recyclable, store carbon?

5. Create a report or presentation to share the product you selected, the positives and negatives of the product (with evidence gathered from your own testing or from reading reviews), the nanocellulose innovation you have developed to solve the problem and the extra benefits that will come with using nanocellulose to improve this product.

	Exemplary	Proficient	Developing	Beginning
Research & Citations	More than 1 additional source	At least one source in addition to information from The Greener World of Tomorrow is used and cited.	Information from The Greener World of Tomorrow is used and cited.	No evidence is used/cited.
Characteristics/ Properties of Product & Issues with Product Design or Product Performance	Includes all requirements to be Proficient and BOTH of the following as described for being proficient: □ Design Issues □ Performance Issues	Product Description includes: □ What it is □ What it is supposed to do □ What it does well And ONE of the following: □ Design Issues (Observed by student testing or cited in product reviews) □ Performance Issues (Observed by student testing or cited in product reviews)	Missing 1-2 criteria required to be proficient	Missing 3 or more criteria required to be proficient
Description of how use of Nanocellulose will improve Product Design OR Product Performance	Includes all requirements to be proficient but has at least two pieces of evidence that supports nanocellulose being used in this way	New/Improved Product demonstrates: □ Innovative use of nanocellulose to solve an issue/ problem □ Maintained (or improved) function or performance □ At least one piece of evidence that supports nanocellulose being used in this way	Missing 1 criteria required to be proficient	Missing 2 or more criteria required to be proficient
Additional Benefits of Utilizing Nanocellulose to Improve this Product	At least one additional benefit that is not related to sustainability or climate change and piece of evidence that supports it.	Explanation of additional benefits covers □ Sustainability of product and resources used to produce it □ How it helps combat climate change □ At least one piece of evidence that supports each of the additional benefits shared	Missing 1 criteria required to be proficient	Missing 2 or more criteria required to be proficient.
Product & Presentation	Product and/or Presentation exceeds expectations for Proficient; Minimal/no errors	Product and/or Presentation is well organized, easy to follow and supported with relevant evidence and graphics (if possible); Errors do not distract from content.	Not organized well; Some evidence/ information is irrelevant; Errors are distracting	Poorly organized; No relevant evidence/ information; Many errors

RECOMMENDED RESOURCES

- Nanotechnology – U.S. Forest Service, Forest Products Lab website
  https://research.fs.usda.gov/fpl/forestproducts/nanotechnology
- Nanotechnology – U.S. Forest Service website
  https://research.fs.usda.gov/forestproducts/nanotechnology
- Transparent Wood Could Be the Window of the Future, Amy Androff and Robert Westover, Jul 29, 2021
  https://www.usda.gov/media/blog/2020/10/01/transparent-wood-could-be-window-future
- A Wood Product Stronger than Steel that Could Change the World, Tom Moreland & Shannon Kelleher, Aug 02, 2021
  https://www.usda.gov/media/blog/2018/03/16/wood-product-stronger-steel-could-change-world
- Cellulose nanofiber manufacturing technology and application development – Nippon Paper Group website
  https://www.nipponpapergroup.com/english/research/organize/cnf.html
- Products using Nanocellulose in Japan – Nanocellulose.com website
  https://nanocellulose.biz/en/products/
- Bridging the Gap: Concrete may provide new market opportunities for forest materials – U.S. Forest Service website
  https://www.fs.usda.gov/inside-fs/delivering-mission/deliver/bridging-gap-concrete-may-provide-new-market-opportunities
- Wood is the new concrete - #forestproud website
  https://woodisthenewconcrete.com/
- Smaller than a Woodchip: Packaging for a Sustainable Future – U.S. Forest Service webinar
  https://research.fs.usda.gov/fpl/products/multimedia/webinars/smaller-woodchip-packaging-sustainable-future
- Nanotechnology – U.S. Forest Service YouTube video
  https://www.youtube.com/watch?v=FPyfZIDcM_E&t=24s
- Just add wood: a microscopic climate solution - #forestproud website
  https://forestproud.org/2022/11/07/just-add-wood-microscopic-climate-solution/

- Nanocellulose Production at UMaine – University of Maine website
https://umaine.edu/nanocellulosevalley/explore-the-possibilities-of-cnf/

- Building bone and beyond – University of Maine website
https://umaine.edu/nanocellulosevalley/2020/10/26/building-bone-and-beyond/

- Revolutionizing construction materials – University of Maine website
https://umaine.edu/nanocellulosevalley/2020/10/26/revolutionizing-construction-materials/

- Transforming paper – University of Maine website
https://umaine.edu/nanocellulosevalley/2020/10/26/transforming-paper/

- New wood nanofiber biomaterial steals strength record from spider silk, Michael Irving,
New wood nanofiber biomaterial steals strength record from spider silk (newatlas.com)

- Wood to supercapacitors: Sustainable highly conductive electrode materials from ultrathin carbon nanofiber aerogels derived from nanofibrillated cellulose,
https://www.sciencedaily.com/releases/2018/05/180524112348.htm

- Graphene made out of wood could help solve the e-waste problem, Luke Dormehl
https://www.digitaltrends.com/cool-tech/wood-based-graphene/

- Making graphene out of wood for degradable electronics, Michael Irving
https://newatlas.com/laser-wood-graphene/50705/

- Nanowood - A new Wood Insulator to Replace Styrofoam, Lakshmi Supriya Nanowood –
A New Wood Insulator to Replace Styrofoam (azobuild.com)

- Wood to build human body parts - and other bio-innovations, Irene Banos Ruiz,
Wood to build human body parts — and other bio-innovations | Environment | All topics from climate change to conservation