Nature-Inspired Design: A PictureSTEM Curriculum for Elementary STEM Learning

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PURDUE ENGINEERING

ENGINEERING EDUCATION

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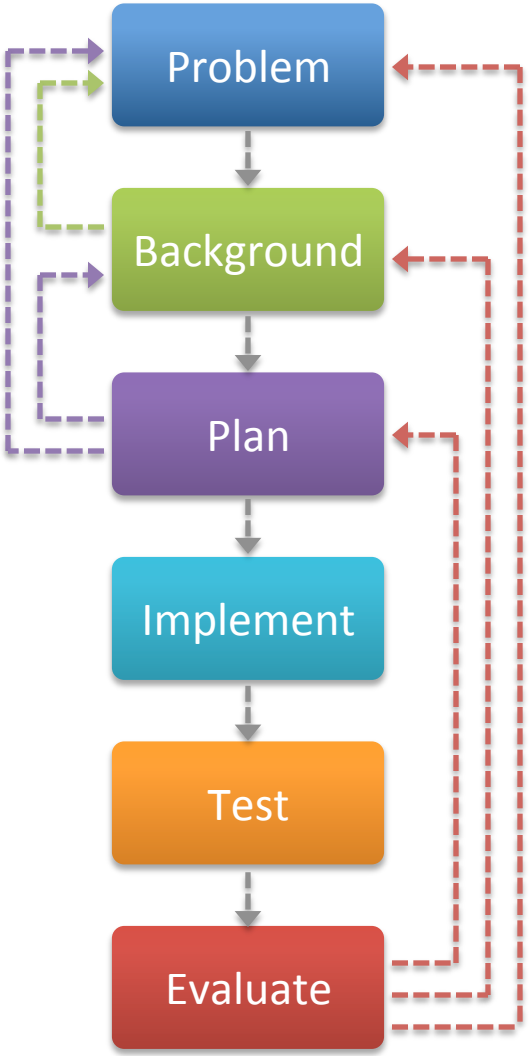
INSPIRE!

https://sites.google.com/a/umn.edu/picturestem/

STEM Integration in Elementary

- Recent National reform documents
  - have identified the importance of scientific and technological literacy to sustain the U.S economy (NRC; 2009, 2012)
  - increase the number of students pursuing STEM fields to remain competitive in the global economy
- Link between Science and Engineering in NGSS
- We also need to get more students interested in STEM fields, children's exposure to engineering should begin in elementary school (NAE 2009, NRC, 2012).

An Engineering Design Process



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Problem

(http://www.ewb-usa.org/)

Engineers Without Borders - USA is a 501(c)3 organization (/about-ewb-usa/annual-reports)

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LOCATE A PROJECT

CHAPTER
RENSSELAER POLYTECHNIC INSTITUTE CHAPTER (/chapters/locate-chapter/0/100215)

PROJECT TYPE(S)
WATER SUPPLY
WATER SUPPLY
WATER SUPPLY

PROJECT
Isla popa ii, panama water supply

PROJECT PHASE
Design

PROJECT ADOPTION DATE
September 2010

DIRECTLY AFFECTS
250

FUNDS NEEDED
$0.00

INDIRECTLY AFFECTS
250

THE NEED

Popa II does not have adequate means to access or store potable water. Beyond the demands of walking to collect water in dry seasons, skin diseases, sickness, diabetes, and low blood pressure may be results of the water shortage. During rainy seasons, water is abundant; however, in dry seasons, contaminated wells and storage tanks hold low levels of water, which are rationed until the rain returns. Observed health behaviors include defecation near water sources and low water consumption and provide reason to believe that hygiene and health education are also potential areas of improvement.

DOWNLOADS!
Project information as a PDF (/projects/locate-project/1/8801/pdf)

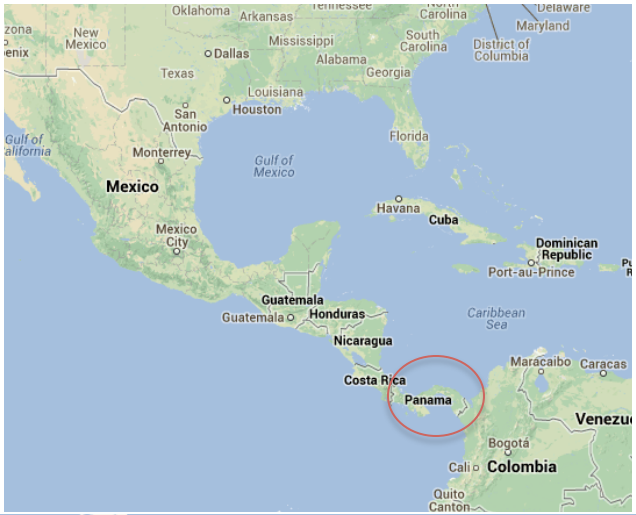
(https://ssl.charityweb.net/ewbusa/?Custom3=100215&Custom4=8801)

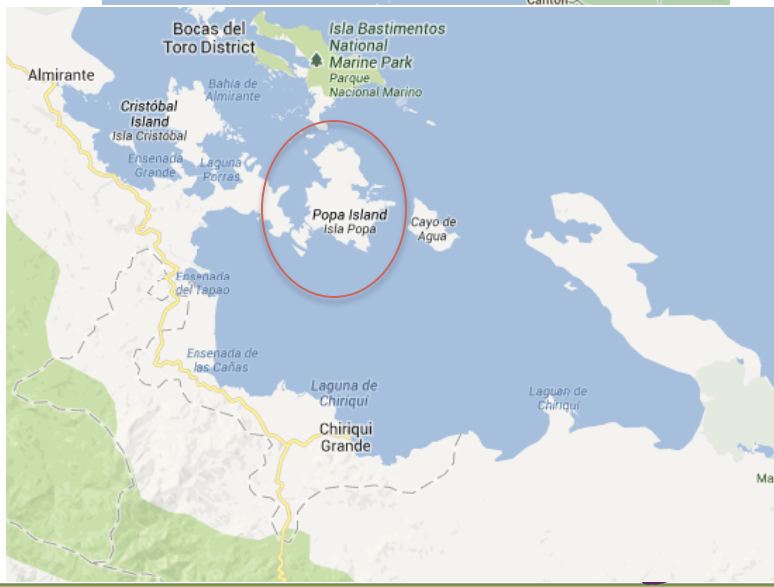
PROJECT SCOPE

The primary objective of the EWB-USA RPI Student Chapter's project is to develop a clean and reliable water system by collaborating with community members. After a January 2012 assessment trip, the chapter aims to continue developing relationships with the recently created Water Committee and assess the water quality in order to develop feasible designs. The information gathered from community members and technical data will determine what type of system must be implemented to best solve the water supply and contamination problem.

FUTURE INVOLVEMENT

Following the recent assessment trip, the EWB-USA RPI Student Chapter will continue to collect and analyze specific data to understand the functional criteria of the final water system and begin developing prototypes. The water system will be implemented in collaboration with community members. After the system's completion, the chapter will monitor the sustainability of the design and consider additional projects to contribute to improved living conditions in Popa II.

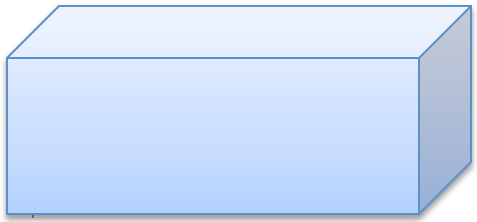




Problem

Planning the Collection Device

- The Engineers Without Borders chapter has let us know that the water collection tanks they will be designing will have two parts:
  - Top: a device that will allow water to enter into the collection tank in an efficient manner and is inspired by Nature
  - Bottom: A rectangular prism shaped collection tank to store the water. This will have a spigot to release the water.



How would we test our designs?

- How will we know if our design is successful?

- Your designs would be evaluated based on the Following criteria

Test #1 **Score:**

Volume Score:

>800 (too big)	500- 800 (2.5 – 4 mo)	240- 500 (1.5 – 2.5 mo)	<240 (original)
5	10	5	0

Total Materials Score:

< $350	$350-$500	$500-$600	$600-$700	$700-$800	$800-$1000	>$1000
15	10	8	6	4	2	0

Rain Catching Score: Is your top design larger than the base?	**Yes** 5	**No** 0
Water Collection Test 1: Is your design able to collect water?	**Yes** 5	**No** 0
Water Collection Test 2: The percentage of water collected?	**>50 %** 10	**25-50%** 5	**0-25%** 0
Inspired by Nature: Did you explain how your design was inspired by nature?	**Yes** 5	**No** 0
Total Score		

Materials Score

- Cost is an important constraint in engineering and also in our design challenge:

Base Material:	Cost:
Foam	$1/cm^2
Adhesive Cost – 30 cm	$20.00
Additional Materials:	**Cost:**
Masking Tape – 15 cm	$5.00
Duct Tape – 15 cm	$10.00
Plastic Wrap – 100 cm^2	$20.00
Aluminum Foil (reg)- 100 cm^2	$30.00
Aluminum Foil (heavy duty)- 100cm^2	$60.00
Copy Paper- 100 cm^2	$10.00
Wax Paper - 100 cm^2	$20.00
Foam sheet - 100 cm^2	$40.00
Craft Stick (jumbo)	$20.00
Craft Stick (regular)	$10.00
Pipe cleaner (jumbo)	$50.00
Pipe cleaner (regular)	$30.00
Cotton Ball	$10.00

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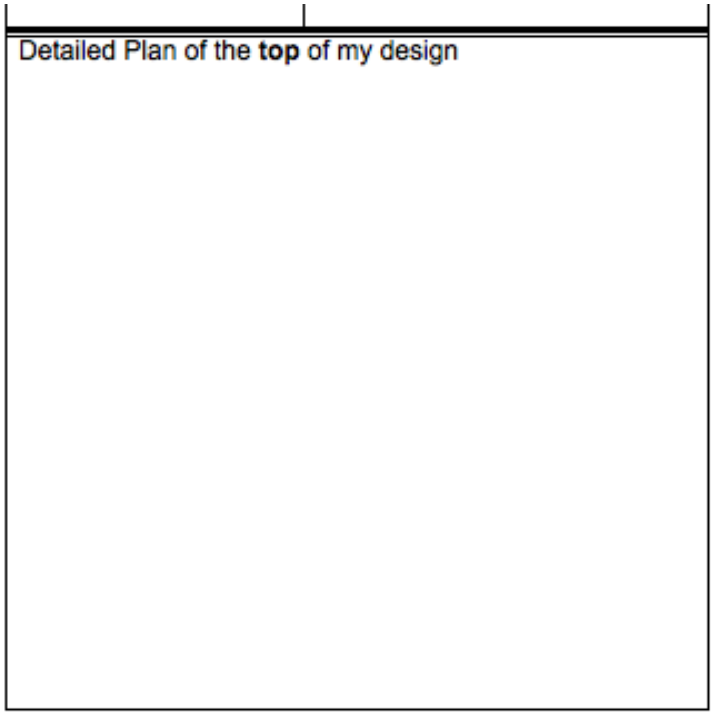
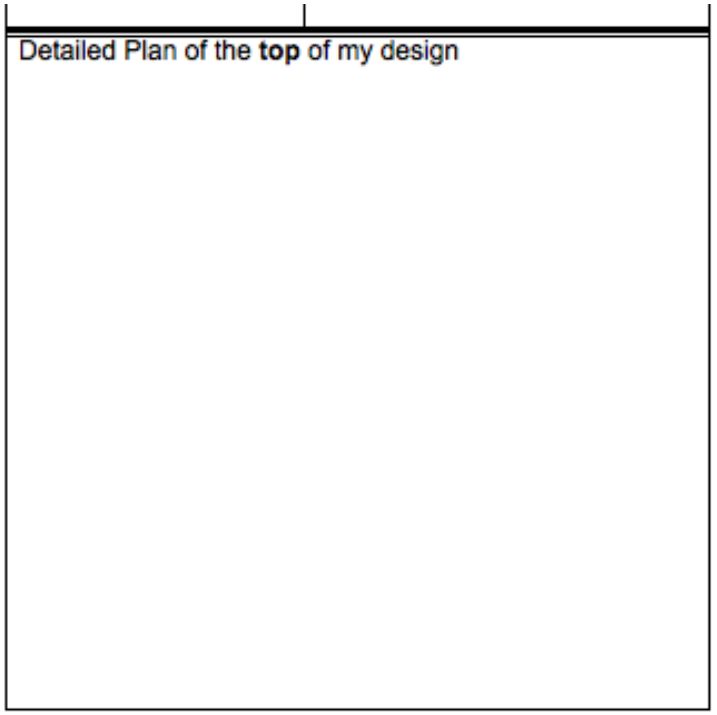
Brainstorm ideas

- Individually: Brainstorm possible solutions for the top design

Idea #1



Idea #2



Reflect on your designs

- At your table
  - Share your favorite design idea
  - Brainstorm what information would help you to design a better top?

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So… How was this developed?

- We used:
  - Clements' (2007) Guide to Research on Curriculum Development
  - Framework for Quality STEM Integration Curriculum
- Why:
  - Need for STEM integration curricula in elementary classroom where time and resources are limited

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Clements' Curriculum Research

A Priori Foundations

1. Subject Matter A Priori Foundation
2. General A Priori Foundation
3. Pedagogical A Priori Foundation

Learning Model

4. Structure According to Specific Learning Model

Evaluation

5. Market Research
6. Formative Research- Small group
7. Formative Research- Single classroom
8. Formative Research- Multiple classrooms
9. Summative Research- Small scale
10. Summative Research- Large scale

(Clements, 2007)

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A Framework for Quality STEM Integration Curriculum

Quality STEM Integration Curriculum should:

- have a meaningful, motivating, and engaging **context**.
- have learners participate in an **engineering design task** for a compelling purpose that involves problem-solving skills and ties to context.
- allow learners to **learn from failure** and then have the opportunity to **redesign**.
- include appropriate, standards-based science or mathematics **content**.
- teach content with **student-centered pedagogies**.
- promote **communication** skills and **teamwork**.

Moore et al., in press

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Objectives

- Create curriculum modules that follow a new model for STEM integration
  - Include an engineering component
  - Meaningful and intentional connections between STEM fields to highlight interdisciplinary and not a “silo” approach
  - can be tied into literacy instruction.
- Maximum flexibility, but still useful and authentic.
- Develop resources to help integrate engineering into K-6 classrooms.

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Nature – Inspired Design

- Inspired by the 14 Grand Challenges – providing access to clean water, using the idea of Biomimicry, or Nature-Inspired Design to help brainstorm new ideas

Science Connections	Technology & Engineering Connections	Mathematics Connections
• Biomimicry • Animal/plant structures that provide advantages, • Animal Adaptations • Natural systems	• Engineering design • Using nature as inspiration for designs	• Data Analysis • Measurement & Perimeter

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Fifth Grade Unit Overview: Nature Inspired Design					
	Day 1 – Biomimicry	**Day 2** – Volume	**Day 3** –Data Analysis & Volume	**Day 4** – What are Adaptations?	**Day 5** – Plant Adaptations
Literacy Activities	Book: *Nature Got There First: Inventions Inspired by Nature* Strategy: Summarize informational text	Book: *For Good Measure* Strategy: Juicy Words- Vocabulary	Book: *Our World of Water: Children and Water Around the World* Strategy: Compare & Contrast	Book: What do you do When Something Want to Eat You or Island: A Story of the Galapogos Strategy: Making Predictions	Student research on biomes and plant adaptations Strategy: Research Skills
STEM integration activities	Students explore an example of nature inspired design before sharing products with classmates	Students learn about volume, how to calculate volume using nets and the relationship between volume and liquid volume	Students use data analysis and average rainfall data to help inform the size/dimensions that they want to use for their storage tank	Rotate through stations, where students explore the advantages that different adaptations provide	Students research a biome and plant adaptations from that biome before sharing their findings with the class
	Day 6 – Planning your design	**Day 7** – Nature-Inspired Design			
Literacy Activities	Book: Biomimicry: Inventions Inspired by Nature Strategy:	Book: *A Cool Drink of Water* Strategy: Author's Message			
STEM integration activities	Students review before the initial brainstorming & planning for engineering design challenge	Create prototype, present to the class and then improve the design			

Unit Overview

Science Background

- Plant and Animal Adaptations
  - Builds content that helps students with design challenge

- Animal Adaptation Stations
  - Practice together
  - Present it to the group

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Adaptation Stations

- The stations include:

Body Parts/Structure

– Webbed Feet
– Claws
– Beak Shape
– Wings
– Eye Size

Body Coverings

– Camouflage
– Scales
– Mimicry

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Nature Inspired Design – Plant Adaptations

- Modified Version – 3 options

Background

Drip Tips	Bromeliad	Cloud Forest
		 
Many rainforest leaves has also developed adaptations, such as drip tips to allow water to easily run off. They can also help to direct water at the plant's roots.	The shape and arrangement of the leaves capture and store water in the plant, in a tank that also harbors a mini-ecosystem of bacteria, larvae, tadpoles, etc.	Due to the shape of the trees and their needles, these trees shed snow easily, and they retain their needles through the winter. The needles are also well-adapted to this climate with thick waxy coatings and small surface area, to resist cold conditions and minimize water loss while allowing snow to shed off of them easily.

Background Knowledge

- Top Design Inspired by Nature
  - What plant adaptations might be helpful?
  - Brainstorm at your table

Plant Adaptation	Advantage that provides	How could that help with this design

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Create a group plan

- With your group:
  - Work together to come up with a single, detailed design
  - Make sure it includes a list of materials

Base Material:	Cost:
Foam	$1/cm^2
Adhesive Cost – 30 cm	$20.00
Additional Materials:	**Cost:**
Masking Tape – 15 cm	$5.00
Duct Tape – 15 cm	$10.00
Plastic Wrap – 100 cm^2	$20.00
Aluminum Foil (reg)- 100 cm^2	$30.00
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Design and Redesign!

Plan

Implement

Test

Evaluate

- Implement the plan for the top of the water collection tank, test the design, and evaluate it.

- Redesign is important step for students
  - Allows multiple solutions & iterations
  - Build upon failures and towards success
  - Makes the reflection useful and intentional

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Lesson 7: Design Examples

- Inspired by Nature

Leaves gather water: geophytes

1 of 1 Albuca namaquensis / buildingades.. / License (cc) BY-NC-ND

Leaves of geophytes collect and retain water from fog and dew by morphological adaptation of their aerial parts.

Leaves channel dew as water source: Welwitschia

Module Overview (K-5)

Grade	Unit Title	Science Connections	Engineering & Technology Connections	Mathematics Connections
K	Designing Baskets	• Sorting by properties • Nature vs. human-made	• Engineering design with an emphasis on testing • Weaving to make paper stronger	• Patterns • Counting
1	Designing hamster habitats	• Animals, basic needs, animal habitats • Designed and natural systems	• Engineering design with an emphasis on testing ideas • Design a hamster habitat and test it	• Characteristics of basic shapes and use those to compose and decompose objects, • Making numbers 0 - 20
2	Toy Box Organizer	• Physical properties and characteristics (color, size, shape, weight, texture, flexibility, strength and the types of materials in the object)	• Engineering Design with an emphasis on materials • Importance of materials	• Standard units of measurement • Understand length as a measurable attribute; • use tools to measure length
3	Traveling to the Moon	• Gravity • Solar system • Moon and moon phases	• Engineering Design • Modifications to fit new environments • Simulations	• Multiplication • Understanding of fraction as numbers • Measurement with distance and time
4	Countdown Clock	• Energy • Electricity • Circuits • Compare insulators and conductors of electricity	• Engineering Design with an emphasis on constraints, • Test/evaluate solutions	• Modeling • Cost component • Polygons • Collect/organize data
5	Nature Inspired Design	• Animal/plant structures that provide advantages, • Natural systems	• Engineering design • Using nature as inspiration for designs	• Algebraic Thinking and Recognizing Patterns • Interpret multiplication as scaling • Geometry & Measurement

Thank you

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