



RELEASE VERSION 1 – 4/6/2017



S.T.E.M. EDUCATION PROGRAM GUIDE

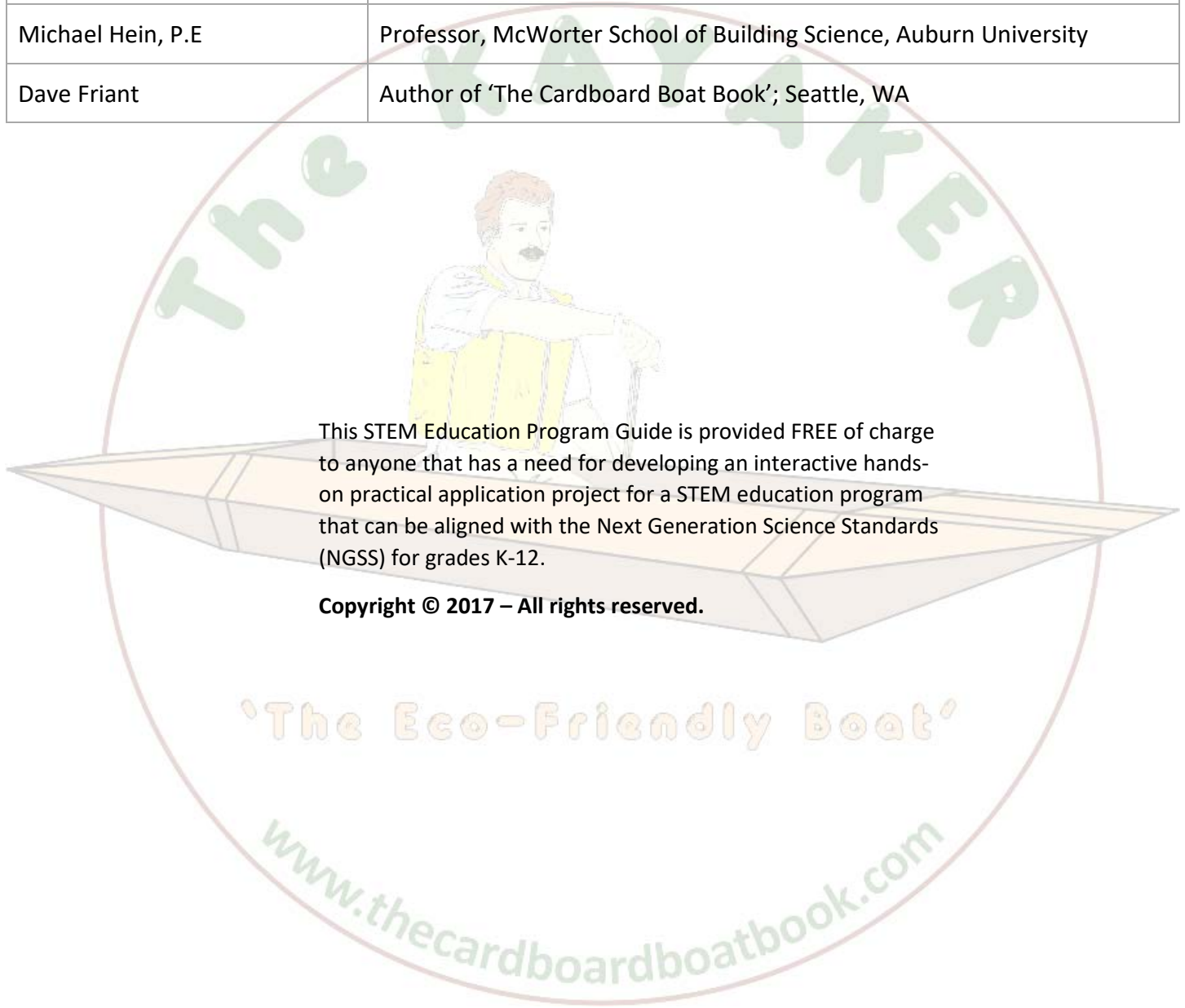
For use with 'The Cardboard Boat Book'

A Program Guide for implementing a cardboard boat building project within an educational setting to teach principles of Science, Technology, Engineering and Mathematics

Contributors

I want to thank the following people for their contribution to the development of this STEM Program Guide.

NAME	AFFILIATION
Stephanie Bowser	Science Educator; Concord, New Hampshire
Claire Lund	Associate Principal/Vice President; Bedford, New Hampshire
Michael Hein, P.E	Professor, McWorter School of Building Science, Auburn University
Dave Friant	Author of 'The Cardboard Boat Book'; Seattle, WA



This STEM Education Program Guide is provided FREE of charge to anyone that has a need for developing an interactive hands-on practical application project for a STEM education program that can be aligned with the Next Generation Science Standards (NGSS) for grades K-12.

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'The Eco-Friendly Boat'

www.thecardboardboatbook.com

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Introduction to the STEM Education Program Guide for 'The Cardboard Boat Book'

Thank you for taking the time to familiarize yourself with the **purpose** and **intent** of the *STEM Education Program Guide* for *The Cardboard Boat Book*.

The **purpose** of the **STEM Education Program Guide** is to assist educators to teach science, technology, engineering, and math, within the interactive hands-on practical application of building a 'Cardboard Boat Book' boat, and if required, aligned with the Next Generation Science Standards (NGSS). Not only are these boats fun to build they are chocked full of science, technology, engineering, and math that can be used to engage students in exciting and lucrative careers in STEM. The guide is also used as a corporate team building project over the course of a 3-day timeframe. I have personally been involved in 2 team building projects and this project brings people together like nothing else.

The **intent** of this program guide is to provide a framework from which you can develop the details of your NGSS-based curriculum or project. For each task in the **preparation**, **building**, and **waterproofing** of a 'Cardboard Boat Book' boat, the guide will identify STEM knowledge that is required for each task and which can be developed during your education sessions for your educational requirements.

Utilizing the framework we have prepared you will be able to guide and instruct your students to develop skills such as;

- **Leadership and project management skills**
- **Working with a budget**
- **Managing resources**
- **Develop teamwork skills**
- **Following instructions**
- **Skills including engineering drawing & dimensioning**
- **Basic math, simple geometry, and trigonometry concepts**
- **Using tools properly and safely**
- **Understanding product manufacturing concepts**
- **Learning about engineering properties of materials**
- **Working safely with materials & contact cement**
- **How to paint & cleanup**
- **Science of Buoyancy & Stability of floating objects**

A workflow diagram of all tasks required to build a 'Cardboard Boat Book' boat is found on page 5. The workflow tasks have been developed in parallel with the instructions in 'The Cardboard Boat Book'. In order to benefit from the program guide 'The Cardboard Boat Book' is used in conjunction with your project. 'The Cardboard Boat Book' is available at Amazon.com.

This version of the **STEM Education Program Guide** is currently in final stages of development and the final version will be available as a FREE download with regular revisions to be offered as the program matures.

Please send any and all questions and comments to stem@thecardboardboatbook.com. We welcome any inputs you might have to contribute to this project. All contributors to the guide will be given credit in the guide.

Please follow us on Twitter, [@cardboardboats](https://twitter.com/cardboardboats), to stay updated on this and other NEW projects.

Alignment with the Next Generation Science Standards (NGSS)

Background

In 2010, the National Academy of Sciences, Achieve, the American Association for the Advancement of Science, and the National Science Teachers Association embarked on a two-step process to develop the *Next Generation Science Standards* (NGSS). The first step of the process was led by The National Academies of Science, a non-governmental organization commissioned in 1863 to advise the nation on scientific and engineering issues. On July 19, 2011, the National Research Council (NRC), the functional staffing arm of the National Academy of Sciences, released the *Framework for K–12 Science Education*. The *Framework* was a critical first step because it is grounded in the most current research on science and scientific learning, and it identifies the science all K–12 students should know.

Why Next Generation Science Standards (NGSS)?

The world has changed dramatically in the 15 years since state science education standards' guiding documents were developed. Since that time, many advances have occurred in the fields of science and science education, as well as in the innovation-driven economy. The U.S. has a leaky K–12 science, technology, engineering and mathematics (STEM) talent pipeline, with too few students entering STEM majors and careers at every level—from those with relevant postsecondary certificates to PhD's. We need new science standards that stimulate and build interest in STEM.

The current education system can't successfully prepare students for college, careers and citizenship unless we set the right expectations and goals. While standards alone are no silver bullet, they do provide the necessary foundation for local decisions about curriculum, assessments, and instruction.

Implementing the NGSS will better prepare high school graduates for the rigors of college and careers. In turn, employers will be able to hire workers with strong science-based skills—not only in specific content areas, but also with skills such as critical thinking and inquiry-based problem solving.

Engineering Design in the NGSS (An excerpt from NGSS)

The *Next Generation Science Standards* (NGSS) represent a commitment to integrate engineering design into the structure of science education by raising engineering design to the same level as scientific inquiry when teaching science disciplines at all levels, from kindergarten to grade 12. There are both practical and inspirational reasons for including engineering design as an essential element of science education.

The NGSS are Standards, not Curriculum

The NGSS are standards, or goals, that reflect what a student should know and be able to do—they do not dictate the manner or methods by which the standards are taught. The performance expectations are written in a way that expresses the concept and skills to be performed but still leaves curricular and instructional decisions to states, districts, school and teachers. The performance expectations do not dictate curriculum; rather, they are coherently developed to allow flexibility in the instruction of the standards. While the NGSS have a fuller architecture than traditional standards—at the request of states so they do not need to begin implementation by “unpacking” the standards—the NGSS do not dictate nor limit curriculum and instructional choices.

Instructional Flexibility

Students should be evaluated based on understanding a full Disciplinary Core Idea. Multiple Scientific and Engineering Practices are represented across the performance expectations for a given Disciplinary Core Idea. Curriculum and assessment must be developed in a way that builds students' knowledge and ability toward the performance expectations. As the NGSS are performances meant to be accomplished at the conclusion of instruction, quality instruction will have students engage in several practices throughout instruction.

Because of the coherence of the NGSS, teachers have the flexibility to arrange the performance expectations in any order within a grade level to suit the needs of states or local districts. The use of various applications of science, such as

medicine, forensics, agriculture, or engineering, would nicely facilitate student interest and demonstrate how scientific principles outlined in the *Framework* and NGSS are applied in real world situations.

Cardboard Boats and NGSS

The process of building a boat from *The Cardboard Boat Book* can be aligned with the NGSS within all of the grade bands identified in the NGSS standard. The key here is to align the knowledge base required to build a boat to the appropriate grade bands. Grade bands are K-2, 3-5, 6-8, and 9-12. It goes without saying that the earlier grade bands will need more adult supervision and will not possess the knowledge base or decision making abilities than the later grade bands. Therefore, in the earlier grade bands more of the construction process will need to be performed by the educators on behalf of the students.

In each grade band applicable STEM concepts will be introduced into the project. I have identified and listed applicable concepts and learning objectives for each task in the process of building a 'Cardboard Boat Book' boat. The concepts are listed in the 'Education Notes' located in the right hand column of all 3 phases of building a boat beginning on page 9.

Building boats with cardboard is a fun and educational project that engages people of all ages, disabilities, and gender, and when combined with a well thought out curriculum plan for teaching the 3 dimensions outlined in the NGSS Framework, cardboard boat building provides students with a context for the content of science, how science knowledge is acquired and understood, and how the sciences are connected through concepts that have universal meaning across the disciplines.

Specifically, an NGSS core idea for K-12 science instruction should:

1. *Have broad importance across multiple sciences or engineering disciplines or be a key organizing principle of a single discipline.*
2. *Provide a key tool for understanding or investigating more complex ideas and solving problems.*
3. *Relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge.*
4. *Be teachable and learnable over multiple grades at increasing levels of depth and sophistication. That is, the idea can be made accessible to younger students but is broad enough to sustain continued investigation over years.*

Building a boat from 'The Cardboard Boat Book' is a project that satisfies a core idea in engineering, technology, and applications of sciences, can be aligned with all education bands in K-12, and is an engaging project that will be remembered for a lifetime.

Cardboard boat building is enjoyed by all ages and groups of people, including higher educational institutions, corporate team building events, local community events, hobbyists, and sportsmen around the world.

Overview of Building 'The Kayaker'

Building a cardboard Kayaker is a project that can be sub-divided into 3 distinct phases. All 3 phases are required to make and prepare a cardboard Kayaker for use in water. As a frame of reference, I can cut out all 21 pieces of cardboard, make the 7 parts, and cement the 7 parts together in 10 hours.

The 3 phases are:

1) Prerequisites for Building 'The Kayaker'

- Setting the stage and expectations for an educational class
- Understanding the design and construction of The Kayaker – What is it and how does it work?
- Gathering together the Tools & Materials required to build The Kayaker
- Explain how the book instructions are organized to assist the student building process

2) Building 'The Kayaker'

- Step-by-step instructions for building a Cardboard Boat Book Kayaker
 - 7 steps for building 7 components that comprise a cardboard Kayaker
 - Cementing the 7 components together to make the Kayaker

3) Waterproofing 'The Kayaker'

- OPTIONAL: Installing 'Dent-Resistant' Material
- Taping the seams between the 7 components in preparation for waterproofing
- Waterproofing a Kayaker with elastomeric roof paint

The 3 phases conveniently organize the project into individual educational teaching opportunities and can be assigned different STEM topics to explore and learn.

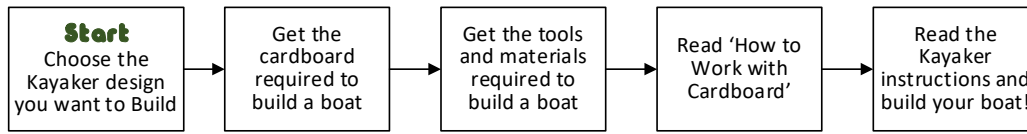
Throughout this document I will present different STEM topics that can be integrated into your curriculum within the 3 distinct phases.

Using this project in an educational setting will teach your students hard skills used in the real world as well as important soft skills such as communication, team work, conflict resolution, compromise, cooperation, following instructions, and more.

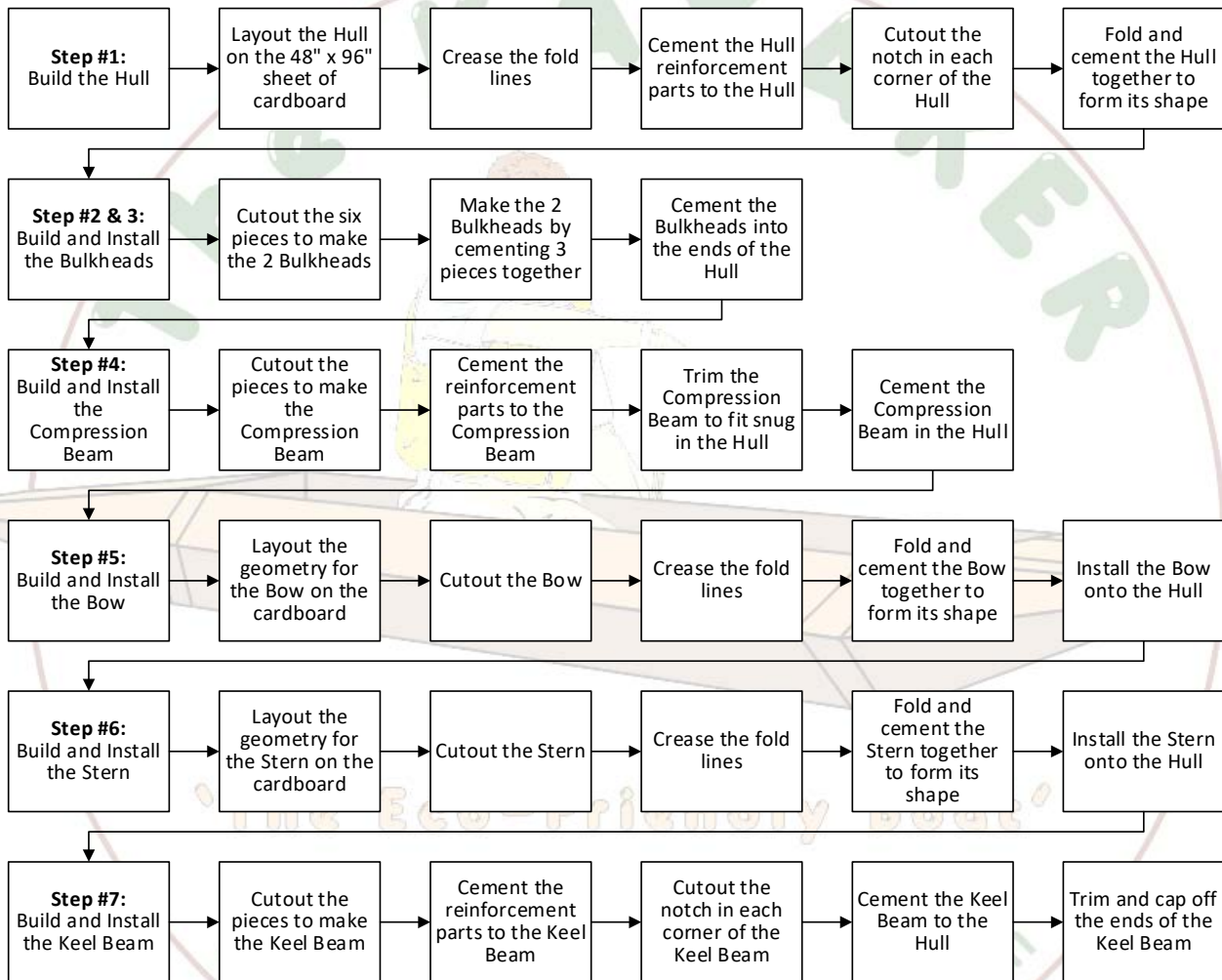
The next page provides a visual workflow diagram of all tasks required to build a cardboard boat, followed by a detailed breakout of each task with personal notes and observations from courses I have taught and recommending STEM skills that can be taught and illustrated throughout the project.

Chronological Workflow Diagram of Tasks for Building 'The Kayaker'

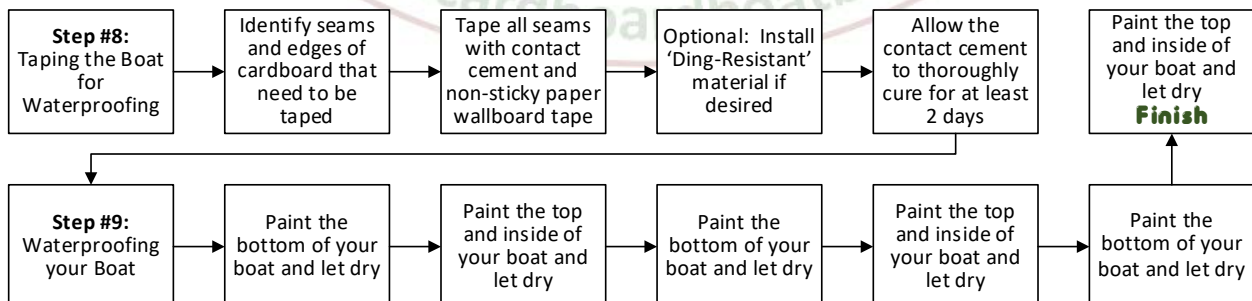
1) Prerequisites to Building 'The Kayaker'



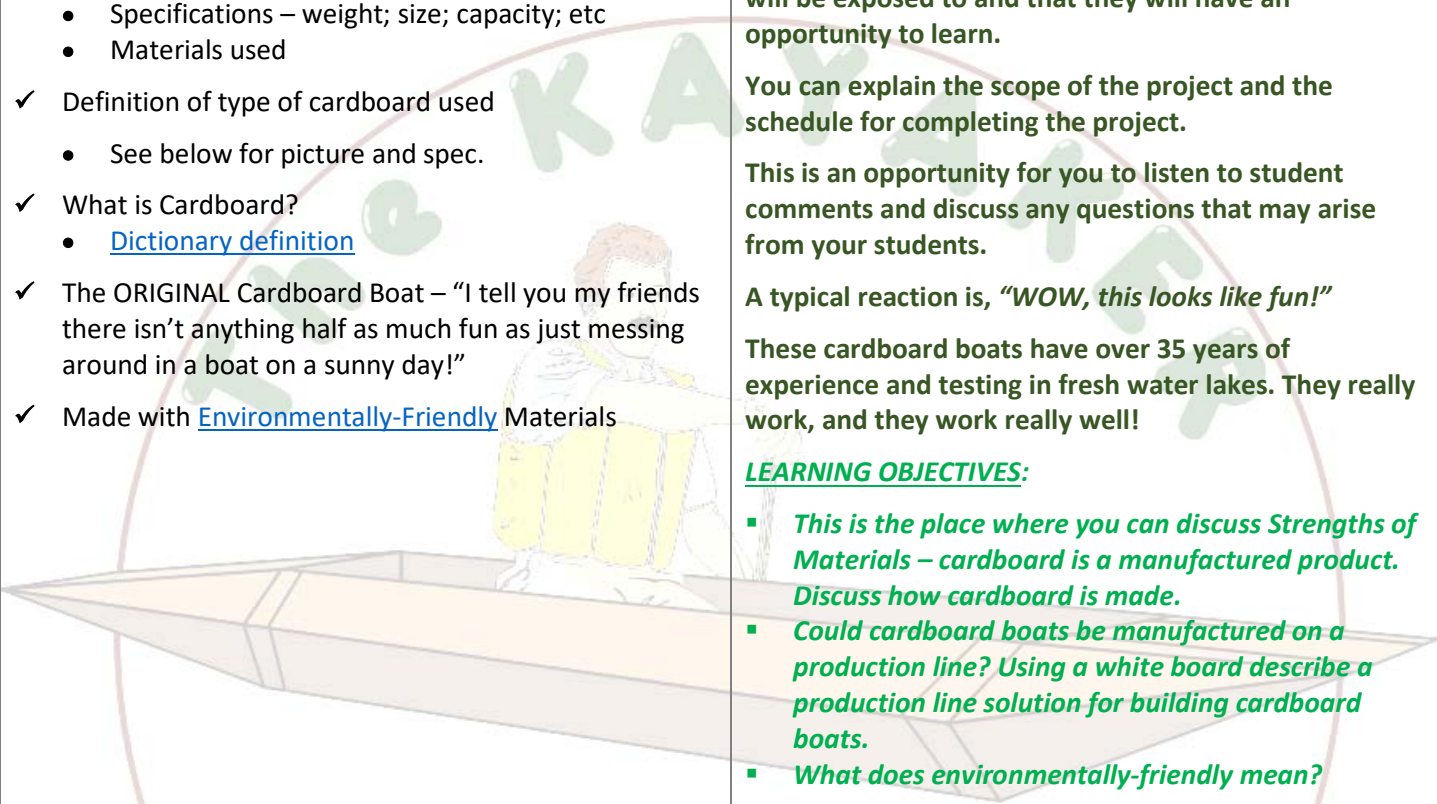
2) Chronological List of Tasks for Building 'The Kayaker'



3) Waterproofing 'The Kayaker'



1) Prerequisites to Building 'The Kayaker'

PREREQUISITES	EDUCATION NOTES
<p>What is a Cardboard Boat? (p.1)</p> <ul style="list-style-type: none"> ✓ Explanation of a 'Cardboard Boat Book' boat. <ul style="list-style-type: none"> • 21 pieces of cardboard are used to make 7 component parts • Specifications – weight; size; capacity; etc • Materials used ✓ Definition of type of cardboard used <ul style="list-style-type: none"> • See below for picture and spec. ✓ What is Cardboard? <ul style="list-style-type: none"> • Dictionary definition ✓ The ORIGINAL Cardboard Boat – “I tell you my friends there isn't anything half as much fun as just messing around in a boat on a sunny day!” ✓ Made with Environmentally-Friendly Materials 	<p>The prerequisites section is where you as an educator introduce and provide the background and purpose of the cardboard boat building project. It allows you to describe the STEM concepts and details that students will be exposed to and that they will have an opportunity to learn.</p> <p>You can explain the scope of the project and the schedule for completing the project.</p> <p>This is an opportunity for you to listen to student comments and discuss any questions that may arise from your students.</p> <p>A typical reaction is, “WOW, this looks like fun!”</p> <p>These cardboard boats have over 35 years of experience and testing in fresh water lakes. They really work, and they work really well!</p> <p>LEARNING OBJECTIVES:</p> <ul style="list-style-type: none"> ▪ <i>This is the place where you can discuss Strengths of Materials – cardboard is a manufactured product. Discuss how cardboard is made.</i> ▪ <i>Could cardboard boats be manufactured on a production line? Using a white board describe a production line solution for building cardboard boats.</i> ▪ <i>What does environmentally-friendly mean?</i>
<p>How Cardboard Boats Work (p.3)</p> <ul style="list-style-type: none"> ✓ Strength is achieved from the geometry of the component parts. Hint: Triangles! ✓ Water resistant coating protects the boat from water damage ✓ Designed using the Principles of Buoyancy and Stability of Floating Objects 	<p>This will be the first general lesson overview for the project. How do Cardboard Boats work? Actually, they work just like any boat works, they are just made from an unconventional material, that's it!</p> <p>This is a good time to hand out the syllabus for the course. Complimentary supporting documentation will be posted on the STEM Education page of 'The Cardboard Boat Book' website. Check back often to download new supporting information to assist you.</p> <p>LEARNING OBJECTIVES:</p> <ul style="list-style-type: none"> ▪ <i>A discussion regarding how geometric shapes are used to gain exponential strength from material that isn't necessary strong in and of itself. Triangles are the most stable and strong geometric shape in the universe, the boats in The Cardboard Boat Book are comprised of triangular shapes...this is a light bulb moment!</i> ▪ <i>This is also the place to introduce the concepts of Buoyancy and Stability of floating objects. You can</i>

drill down on this during class and perform the calculations yourself to validate the Buoyancy and Stability of the boats using Archimedes principles of buoyancy.

- *Calculating the center of gravity and stability factor could be an extra-credit assignment.*
- *STEM topics are age dependent and a discussion at a technical level needs to be appropriate for the age group and knowledge base of the students.*

How to Get Started (what you need to do before you begin building a boat) (p.5-8)

- ✓ Choose which of the Kayaker designs you want to build
 - Straight or Tapered Bow?
- ✓ Get the Corrugated-Cardboard Required to Build a Boat
- ✓ Get the Tools and Materials Required to Build a Boat
- ✓ Read How to Work with Cardboard (p.9)
- ✓ Read The Kayaker Instructions (Begins on p.10)

This section provides students with all the necessary information they need to get started on the project.

There are 2 designs to select from.

I recommend asking a local manufacturer of corrugated cardboard to donate the necessary cardboard sheets to build the boats. Sometimes a manufacturer will sell sheets at a discount to an educational institution. They get the marketing benefit, you get the cardboard you need. It's a win-win for both of you.

It is possible to build these boats using large appliance boxes containing products such as refrigerators and furniture.

Corrugated-Cardboard Required to Build a Boat (p.6-7)

- ✓ [Definition of Cardboard](#)
 - Describe the type of cardboard required to build a boat and provide a picture of double-wall cardboard.



- New Cardboard or Recycled Cardboard (from large appliance and furniture boxes)
- ✓ **Cardboard Specification: MUST use industry-standard 275 lb. test, 1/4" thick, double-wall corrugated cardboard**
 - 2-sheets, 60" x 60" (or larger) for Nosepiece construction
 - [Or optionally, 4 pieces 30" x 60", for 2-piece Nosepiece Construction](#)
 - 1-sheet, 48" x 96" (or larger) for Hull body
 - 2-pieces 48" x 11", required for the Hull reinforcement parts
 - 2-pieces 48" x 10", required for the Hull reinforcement parts
 - 2-pieces 18" x 24" for the Compression Beam
 - 6-pieces 30" x 12" Bulkheads

However you acquire the cardboard for your class you **MUST** adhere to the cardboard specification! Without adhering to the cardboard specification the dimensions would need to be adjusted for a thicker cardboard, and do not use thinner single-wall corrugated cardboard. I cannot guarantee the integrity of the final boat without adhering to the cardboard specification. I provide a very clear industry standard specification for you to work with.

NOTE: Search the internet for 275# test double-wall cardboard sheets. There are lots of sources and reasonable prices. Cost for cardboard for one boat should be between \$20 and \$25 (Pricing from 2017, and is subject to change over time).

LEARNING OBJECTIVES:

- *Acquiring the correct cardboard is a lesson in following instructions, putting a plan together, and researching sources. Skills that are useful and required in any career.*
- *How well did students listen to and retain the knowledge regarding the designs and how cardboard boats work? This could be included in a test.*
- *Develop a budget for building a boat. A Project Management skill.*

Tools and Materials Required to Build a Boat (p.8)

- ✓ **Tools:** (See the book for simple pictures of all tools)
- **Pencil** for drawing lines on cardboard
 - **Tape Measure** for measuring lines on cardboard (up to 8 feet long)
 - **Straight edge** for drawing straight lines and cutting cardboard (30" minimum)
 - **Utility knife** for cutting cardboard
 - **Screen door roller, or other tool,** for creasing cardboard
 - There are many options for tools used to crease cardboard
 - Whatever you use needs to be capable of creasing long straight lines
 - A section of tongue and groove flooring works well using the tongue to crush and slide along crease lines.
 - [Simple beam compass](#) for laying out the nosepiece geometry
 - A simple beam compass can be made using a tape measure, a nail, and a pencil
 - See [YouTube](#) for videos on making a beam compass.
 - **Disposable 1-1/2" wide brush** for applying contact cement
 - **Disposable 3" to 4" wide brush** for painting boat
- ✓ **Materials:**
- 1-roll of Paper Drywall Tape
 - Found at hardware and do-it-yourself home stores
 - ½-gallon of 'Eco-Friendly' Contact Cement
 - [Recommend Titan DX Premium Contact Cement](#)
 - 1-gallon of 'Eco-Friendly' Acrylic Elastomeric Paint
 - [Recommend Ames Research Elastomeric coatings](#)

All the required tools are simple and readily available at any home improvement store including the non-sticky paper drywall tape.

There are a number of water resistant / water proof materials that can be used. I have found that an acrylic elastomeric roof paint provides superior protection from water damage. Using this type of paint it is possible to use one of these boats for many years. I have one boat I built 35 years ago that is still in use today.

The product I use is from Ames Research in Oregon. Their product can be found at many Ace Hardware stores and other home improvement stores. If you want to use this product line you can find a local reseller on the [Ames Research website](#).

I waterproofed my first boat for the physics class by painting it inside and out with contact cement. It worked but was temporary. I then spent many years trying all types of coatings. Many worked, but some were too expensive for everyone to use. The Ames Research products are a little pricey but their products work very well.

Using an acrylic product it is possible to take it to a paint store and have it colored to your desired color. I purchase 'Ames Block & Wall' in white and then have it colored a brown cardboard color.

LEARNING OBJECTIVES:

- *See how creative students can get with their selection of a waterproofing product. What is their justification for their selection? Physical properties of their selection, i.e.-why is their selection a good choice?*

How to Work with Cardboard (p.9)

- ✓ **Measuring cardboard**
- Units of measure – All dimensions are in inches and ¼, ½, and ¾ partial inch measurements
 - Partial inch – .25 = ¼ inch; .5 = ½ inch; .75 = ¾ inch.
- ✓ **Cutting cardboard**
- How to cut properly and safely
 - How to cut a straight line
- ✓ **Creasing and Folding Cardboard**
- How to crease and fold properly
- ✓ **Gluing, or cementing, Cardboard**
- Proper use of contact cement

Attention to detail when working with cardboard will make the difference between a boat that simply floats and a boat that floats and looks straight and true. Cardboard has some wiggle room for error. It can be smashed and twisted and still glue together and the boat will float.

If students pay attention to the details when working with cardboard their work will pay off in the final product. Boats will be true and straight and look clean and correct. The boats will float straight and perform at its best.

If attention to detail is not taken seriously boats can look lopsided, move through the water with unnecessary drag and can pull to one side or the other.

<ul style="list-style-type: none"> • Challenges using contact cement • What not to do <p>✓ <i>Direction of the Cardboard Corrugation Pattern Matters</i></p> <ul style="list-style-type: none"> • The direction the corrugation lines are oriented contributes to the strength of the component parts • Pay attention to the drawings of the individual cardboard pieces and cut the pieces of cardboard so that the orientation of the corrugation lines flow in the direction shown on each piece 	<p>Students can be very critical of others. If the final boats are judged by peers the smallest of details tend to be considered. Can someone build a perfectly straight and true boat? If so, do they win some sort of aesthetic excellence prize, or badge, or recognition?</p> <p>LEARNING OBJECTIVES:</p> <ul style="list-style-type: none"> ▪ <i>How well can directions be followed? How much attention to detail is good enough? Some students will naturally take this challenge seriously and produce beautiful boats. Does that matter? If all boats float and pass a test is that good enough? For some it is, for some type-A students they will feel they could always do better. Think about how the final aesthetic look will be judged for your class.</i>
<p>Overview of Building ‘The Kayaker’ (p.12)</p> <p>Explain how the instructions are laid out to make the construction as simple as possible</p> <ul style="list-style-type: none"> ✓ Each step includes technical drawings, text instructions, and construction photos ✓ The objective is to use the least amount of words to describe the construction process ✓ Present the process as a visual solution <p>Each component construction process consists of a 3-step process</p> <ul style="list-style-type: none"> ✓ CAD drawings showing the plan view of each piece of cardboard with dimensions ✓ Accompanied with a set of 3D assembly drawings showing the construction of the component. ✓ Accompanied with a few photographs reinforcing the correct final result of the construction goal in finished detail <p>Overview of How the Boats are Constructed</p> <ul style="list-style-type: none"> ✓ 21-pieces of cardboard ✓ 7-component parts ✓ Boat is assembled as the components are made ✓ Seams and edges of cardboard are taped in preparation for waterproofing ✓ Paint with waterproof coating <p>Workflow diagram outlining the building process</p> <ul style="list-style-type: none"> ✓ Click to go to Workflow Diagram above 	<p>Now we get to the important point of understanding how the boats are actually constructed with the tools and materials that have been described up to this point.</p> <p>I have laid this section out in a very logical order for understanding the construction of the boats. I have never had anyone ask for clarification on how to build one of my designs. I will assume this is the case for you and your students. I only say this from experience. Of course, there is always a first time for everything.</p> <p>In order to clearly articulate the construction process I provide 3 pieces of information for each step of the construction process. The 3 pieces of information are;</p> <ol style="list-style-type: none"> 1) Computer drawings of the flat piece of cardboard with dimensions. Used to create and cut out each piece of cardboard. 2) 3-dimensional assembly drawings showing how the part looks and how it fits into the boat assembly. 3) Photographs showing the finished part once it is cemented to the assembly of the boat. <p>Using these 3 pieces of visual information the boats follow a very logical process of construction. The 7 boat parts are constructed in the order of assembly. When you have constructed and assembled the 7th part the boat is finished being constructed.</p> <p>Once constructed the boat seams between component parts are taped in preparation for waterproofing.</p> <p>Once the boat is taped it is painted with 3 coats of elastomeric roof paint to waterproof the cardboard.</p> <p>See the Chronological Workflow Diagram of Tasks for Building ‘The Kayaker’ above for a complete overview of all tasks required to build a cardboard boat.</p>

Now that you have an understanding of how the boats are constructed and what tools and cardboard you need to build a boat you are ready to begin construction of 'The Kayaker'.

LEARNING OBJECTIVES:

- *Hold a general question and answer section with the intent of ensuring everyone in the class has an understanding of how the boats are to be constructed. Answer any questions.*
- *If you plan for your class to build the boats in teams now would be a good time to create the teams.*
- *With 9 weeks in a typical school quarter and 7 components to build it is very reasonable for each class member to build their own boat.*
- *If you want your class to become familiar with the real world of working on a team then maybe the team approach is what you want to encourage.*

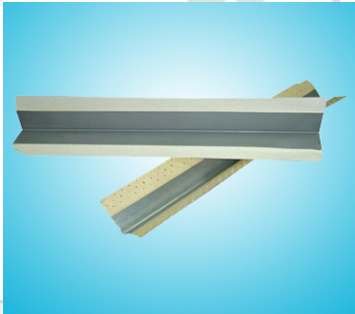
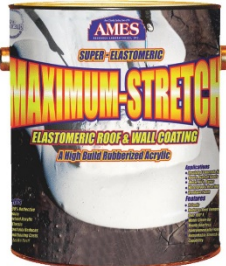


2) Chronological List of Tasks for Building 'The Kayaker'


CONSTRUCTION TASKS	EDUCATION NOTES
<p>Read-this-First</p> <ul style="list-style-type: none"> ✓ Read each instruction before performing the task ✓ Practice performing a task that requires contact cement before actually using the contact cement ✓ Read the 'How to Get Started' page <p>NOTE: See the Unassembled view of The Kayaker on pages 10 and 11 in the book for a pictorial view of all 7 component parts</p>	<p>In this section I provide recommendations from lessons learned. I highly recommend incorporating these lessons learned into your curriculum. There is a reason this section exists.</p> <p>After reading the 'Getting Started' page, you are ready to get started!</p> <p>LEARNING OBJECTIVES:</p> <ul style="list-style-type: none"> ▪ <i>Good time for a kickoff meeting to begin construction. Stress the importance of the following at all times.</i> ▪ <i>Contingency plan (What to do if something goes wrong?)</i> ▪ <i>Mitigation plan (How to fix something that goes wrong?)</i> ▪ <i>Planning & attention to detail (Measure twice cut once)</i>
<p>STEP #1: Make the Hull (p.14-17)</p> <ul style="list-style-type: none"> ✓ Measure the dimensions for the crease lines of each panel on the large Hull sheet ✓ Crease and fold the lines to define the 9 panels ✓ Measure, draw, and cutout the 4 pieces of cardboard to reinforce the Hull ✓ Install reinforcement as shown to panels 2 & 8 ✓ Cut out the, 1" wide x 2 panels long, strip of cardboard from each corner of the Hull as shown ✓ Cement Hull together to form its shape 	<p>The following STEM education lessons are learned throughout all 7 steps of building The Kayaker. The depth of discussion is a variable based on the age and knowledge base of your students.</p> <p>LEARNING OBJECTIVES:</p> <ul style="list-style-type: none"> ▪ <i>How to follow instructions</i> ▪ <i>Basic mathematics</i> ▪ <i>Basic geometry</i> ▪ <i>Planning & attention to detail</i> ▪ <i>Team work collaboration skills</i> ▪ <i>Basic Trigonometry (Big word, fun to work with)</i> ▪ <i>Organization skills</i> ▪ <i>Working with materials</i> ▪ <i>Leadership and Project Management skills</i> ▪ <i>Technical drawing and dimensioning</i> ▪ <i>Buoyancy and stability of floating objects</i> ▪ <i>Strength of Materials</i> ▪ <i>Fitting parts together (assembly manufacturing)</i>
<p>STEP #2 & #3: Make and Install the 2 Bulkheads in the ends of the Hull (p.18-19)</p> <ul style="list-style-type: none"> ✓ Measure, draw, and cutout the 6 pieces of cardboard for the two Bulkheads ✓ Construct two Bulkheads consisting of 3 layers of cardboard each ✓ Install the two Bulkheads into the end of the Hull as shown 	<p>Fitting the Bulkheads inside the ends of the Hull is performed best with one person fitting one end while another person fits the other end as the sides of the Hull are rotated into position around the Bulkheads. Performing this step with 2 people will help ensure the Hull is constructed straight and true.</p> <p>Lessons:</p> <ul style="list-style-type: none"> ▪ <i>How to follow instructions</i> ▪ <i>Basic mathematics</i>

	<ul style="list-style-type: none"> ▪ <i>Basic geometry</i> ▪ <i>Planning & attention to detail</i> ▪ <i>Organization</i> ▪ <i>Working with tools & materials</i> ▪ <i>Team work collaboration skills</i> ▪ <i>Fitting parts together (assembly manufacturing)</i>
<p>STEP #4: Make and Install the Compression Beam inside the Hull (p.20-21)</p> <ul style="list-style-type: none"> ✓ Measure, draw, and cutout the 3 pieces of cardboard for the Compression Beam ✓ Cement the reinforcement pieces in place as shown ✓ Install the Compression Beam to the inside of the Hull as shown 	<p>Depending on how well the Hull has been constructed this step may require trimming the Compression Beam to fit correctly.</p> <p>LEARNING OBJECTIVES:</p> <ul style="list-style-type: none"> ▪ <i>Items in Steps 2 & 3 above plus...</i>
<p>STEP #5 & #6: Make and Install the Bow & Stern to the ends of the Hull (p.22-39)</p> <ul style="list-style-type: none"> ✓ Measure, draw, and cutout the pieces of cardboard for the Bow and Stern <ul style="list-style-type: none"> • 2-pieces of cardboard are required to build the Bow and Stern, or optionally 4-pieces of cardboard are needed to build the Bow and Stern • Using 2 or 4 pieces of cardboard is determined by the size of cardboard that is available ✓ Fold and cement the Bow and Stern together to form their shape ✓ Install the Bow and Stern onto the Hull 	<p>This step requires a team mate to assist in installing or cementing the Bow and Stern to the Hull in order to ensure the Bow and Stern are installed straight and true.</p> <p>LEARNING OBJECTIVES:</p> <ul style="list-style-type: none"> ▪ <i>Items in Steps 2 & 3 above plus...</i> ▪ <i>Basic Trigonometry laying out the geometry of the Bow and Stern</i> ▪ <i>Assembly manufacturing</i> ▪ <i>Following instructions</i> ▪ <i>Planning & attention to detail</i>
<p>STEP #7: Make and Install the Keel Beam on the underside of the Hull (p.40-42)</p> <ul style="list-style-type: none"> ✓ Measure, draw, and cutout the pieces of cardboard for the Keel Beam ✓ 3 pieces of cardboard are needed to build the Keel Beam ✓ Install the reinforcement pieces as shown ✓ Cut out the notch at all 4 corners of the Keel Beam ✓ Install the Keel Beam on the underside of the Hull as shown ✓ Drawing showing the correct contact of the keel with the Hull <ul style="list-style-type: none"> • Explain how to ‘sand’ the Keel Beam to achieve consistent contact with the Hull ✓ Trim the front of the Keel to align with the angle of the bottom of the Bow ✓ Cap both ends of the Keel Beam with a small triangle-shaped piece of cardboard 	<p>The Keel Beam is a structural beam, not just a directional stability part. When you sit in the boat you are sitting on the beam. The beam transfers loads to the Compression Beam and the Bulkheads. It is very important to achieve a strong and tight bond between the Keel Beam and the bottom of the Hull to ensure the structural integrity of the Keel Beam.</p> <p>In order to accomplish this the edges of the Keel Beam that cement to the Hull must achieve contact the entire length of the Keel Beam. Read pages 40-42 in the book and follow the instructions very carefully.</p> <p>LEARNING OBJECTIVES:</p> <ul style="list-style-type: none"> ▪ <i>Follow instructions carefully. Read the book!</i> ▪ <i>Pay attention to detail</i>

3) Waterproofing 'The Kayaker'

WATERPROOFING TASKS	EDUCATION NOTES
<p>OPTIONAL: Installing 'Ding-Resistance' Material (p.44-45)</p> <ul style="list-style-type: none"> ✓ Purpose: Installing 'Ding-Resistance' Material is strictly an aesthetic option to keep your boat looking good for an extended period of time. <ul style="list-style-type: none"> • It DOES NOT provide any structural strength ✓ What it does for the boat <ul style="list-style-type: none"> • Protects top edge of Hull from paddle damage • Protects Keel Beam from lake bottom damage • Protects Compression Beam from leg damage • Protects sides of Hull from dock damage • Protects Bow and Stern from dock damage ✓ Install 90deg. paper-backed drywall/sheetrock corner-bead in the following locations with contact cement <ul style="list-style-type: none"> • Top edge of Hull, • Side of Hull, • Top of Compression Beam, • Bottom of Keel Beam • Front and rear of Nosepieces ✓ When not to use dent-resistant parts <ul style="list-style-type: none"> • Many organized cardboard boat events do not allow the use of any material other than cardboard, glue, tape and paint 	<p>This option is meant for the person that intends to keep their boat as long as they can, as opposed to making the boat for a specific race event with the possibility of recycling it after the event.</p> <p>LEARNING OBJECTIVES:</p> <ul style="list-style-type: none"> ▪ <i>This option is not typically used in an educational setting unless it is assigned as extra-curricular for extra-credit.</i> ▪ <i>However, this option can be used as a discussion to engage students in creative thinking.</i> <p>Picture of paper-backed drywall corner bead.</p> 
<p>STEP #8: Taping Your Kayaker in Preparation for Waterproofing (p.46-49)</p> <ul style="list-style-type: none"> ✓ Taping seams between components and taping exposed cut edges of cardboard <ul style="list-style-type: none"> • Recommended products • Step-by-step Procedure 	<p>This step is critically important to perform correctly. The step-by-step procedure and all the seams that require taping are shown in the book on pages 46-49.</p> <p>LEARNING OBJECTIVES:</p> <ul style="list-style-type: none"> ▪ <i>Learn how to tape seams and clean up.</i>
<p>STEP #9: Waterproofing Your Kayaker (p.50)</p> <ul style="list-style-type: none"> ✓ Water resistant painting <ul style="list-style-type: none"> • Step-by-step Procedure • Recommended products  <ul style="list-style-type: none"> • I purchase 1-gallon of Ames Research Maximum-Stretch. 	<p>This step is critically important to perform correctly. I recommend painting the boats inside and out with 3 coats of waterproof paint.</p> <p>For more information on waterproofing a 'Cardboard Boat Book' boat download the guide titled, How-To Waterproof a Cardboard Boat Book boat guide from the download section on The Cardboard Boat Book website.</p> <p>LEARNING OBJECTIVES:</p> <ul style="list-style-type: none"> ▪ <i>Learn how to paint and clean up.</i> ▪ <i>You will use about a half-gallon painting your boat with 3-coats of elastomeric paint.</i> ▪ <i>You will save a substantial amount of money if you purchase a 5-gallon container and share it.</i>

Tips on Safe & Successful Cardboard Kayaking

TASKS	EDUCATION NOTES
<p>Tips for Safe and Successful Boating (p.52)</p> <ul style="list-style-type: none"> ✓ Coast Guard approved Personal Floatation Devices (PFD) ✓ Boat Safety Web Links 	<p>Safety is paramount when in and around water. The number one thing a person can do is protect themselves by always wearing an approved and correctly fitted life jacket. This is a good time to review safety 'best practices'. Make sure everyone knows that they are required to wear a proper life jacket when testing their boats for this class and during the class final when everyone will float their boats and test their boats against everyone else's boat.</p> <p><u>LEARNING OBJECTIVES:</u></p> <ul style="list-style-type: none"> ▪ <i>Safety first! Always wear an approved life jacket when in and around the water.</i>
<p>Propelling Your Boat (p.52)</p> <ul style="list-style-type: none"> ✓ Inexpensive Plastic Kayak Paddles ✓ Maneuvering Your Boat 	<p>These boats can be easily converted to an electric cardboard eBoat (See below), but they are typically propelled with kayak style paddles. Search the internet for inexpensive kayak style paddles. Plastic kayak paddles can be purchased for less than \$20 USD.</p>
<p>Floating Your Boat (p.52-53)</p> <ul style="list-style-type: none"> ✓ Getting In and Out of Your Boat ✓ Adjusting your Center of Gravity to stabilize your boat <ul style="list-style-type: none"> • Lean forward in the boat. Use paddles to pull yourself through the water. • Do not lean back and push yourself through the water. ✓ Using Director Chairs to get in and out of your boat in shallow water. 	<p>This is worth spending time discussing. The last thing someone wants to have happen to their boat after spending the time to build one is to damage it the first time they put it in the water. The first time I put mine in the water was at the end of the school year event the college sponsored at a local lake park for everyone to enjoy their boat, socialize and see who would either 'Sink-r-Swim'.</p> <p>Thinking ahead I knew I would need to put my boat in the water and get inside it at the shoreline. It was apparent to me that I would most likely scuff up the bottom of the boat while getting in and out of it. I designed a simple solution that would assist me in getting in and out of my boat without risking damaging the bottom of the boat.</p> <p>My solution was simple and practical. I took 2 Directors chairs with me to the park. I place the chairs a boat width apart from each other in about a foot of water. The boat was then placed between the chairs. I placed my arms on one armrest on each side of the boat, lifted my body up and slid the boat underneath myself and lowered myself into the boat...voila! It worked with the help of another person pushing the boat underneath myself as I held myself out of the water with the chairs.</p> <p>I show a pictorial example in the book on how to get in and out of a boat next to a dock in deeper water.</p>

LEARNING OBJECTIVES:

- *Brainstorm as a class on ways you can get in and out of the boats where you plan to hold your end of quarter 'Sing-r-Swim' event. No one wants to damage their boat!*

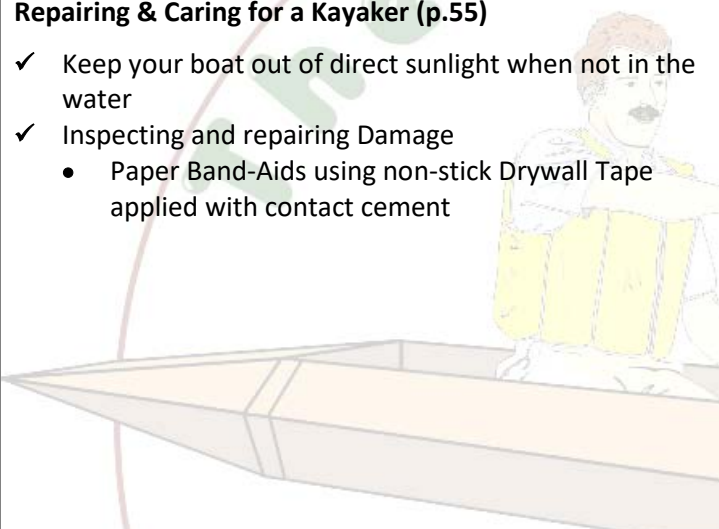
Extra Credit: How-To Make an Electric Powered Cardboard Kayaker

TASKS	EDUCATION NOTES
<p>OPTIONAL: Making an Electric Kayaker</p> <p>✓ See the document titled, 'How-To' Make an Electric Cardboard Boat', located in the download section of 'The Cardboard Boat Book' website.</p>	<p>This option is not typically used in an educational setting unless it is assigned as extra-curricular for extra-credit.</p> <p>This option is however a discussion that can be had to engage students in thinking creatively on how to make an electric powered Kayaker with steering capability.</p> <p><u>LEARNING OBJECTIVES:</u></p> <ul style="list-style-type: none"> ▪ <i>For extra credit.</i>

Transporting & Storing a Cardboard Kayaker

TASKS	EDUCATION NOTES
<p>Transporting a Kayaker (p.54)</p> <p>✓ On top of a Vehicle ✓ Inside a Vehicle ✓ Supports and Tie Downs</p>	<p>Engage students in a team discussion on how best to transport a Kayaker in a vehicle. What type of vehicles will work best? How to secure a Kayaker without damaging it during transportation. No wrong or right answers here. Just a good brainstorm session.</p> <p><u>LEARNING OBJECTIVES:</u></p> <ul style="list-style-type: none"> ▪ <i>Brainstorm as a class on ways to transport a cardboard boat in different types of vehicles. How best to support the boat to protect from damage when in transit.</i>
<p>Storing a Kayaker (p.54)</p> <p>✓ Always store Indoors and off the ground, on a piece of wood or cardboard</p>	<p>Engage students in a team discussion on how best to store a Kayaker when not in use. No wrong or right answers here. Just a good brainstorm session.</p> <p>Although these boats are structurally sound and aesthetically good looking remember they are made from a paper product and there are ways to care for a cardboard boat that are different than a wooden or aluminum boat.</p>

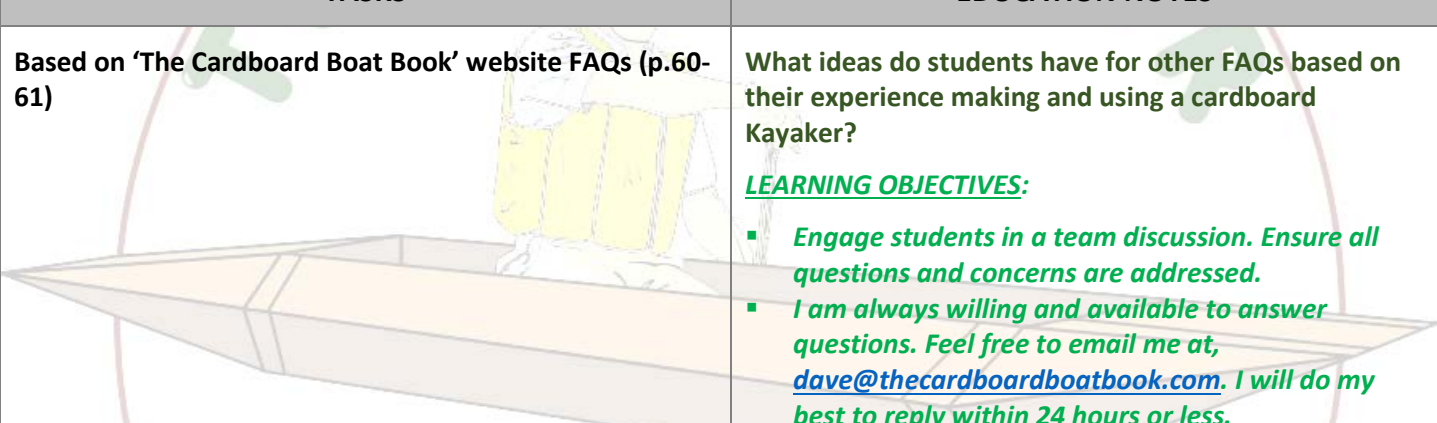
Repairing & Caring for a Cardboard Kayaker

TASKS	EDUCATION NOTES
<p>List of possible accessories (p.55)</p> <ul style="list-style-type: none"> ✓ Should have - Seat cushions; Beverage holder; ✓ Nice to have - Anchor; Cover; Carpeting; Car top carrier; Ice chest ✓ Create your own themed boat design – Dragon; Pirate ship; etc. ✓ Stickers; Custom paint jobs 	<p>What other accessories can students envision? Necessary and nice to have?</p> <p>What ideas do students have for unique identification and decoration? Get creative here. It is your boat, make it unique, have fun!</p> <p><u>LEARNING OBJECTIVES:</u></p> <ul style="list-style-type: none"> ▪ <i>Engage students in a team discussion. No wrong or right answers here. Just a good brainstorm session.</i>
<p>Repairing & Caring for a Kayaker (p.55)</p> <ul style="list-style-type: none"> ✓ Keep your boat out of direct sunlight when not in the water ✓ Inspecting and repairing Damage <ul style="list-style-type: none"> • Paper Band-Aids using non-stick Drywall Tape applied with contact cement 	<p>Cardboard Boats are made with an unconventional boat building material and as such they should be handled with care. After many hours of boating with these boats I have determined that the cardboard can slightly expand if allowed to sit in direct sunlight for an extended period of time. It is highly recommended to keep an eye on your boat to ensure it is not stressed when allowed to sit in direct sunlight.</p> <p>There are times when a boat will bang into a dock and break through the paint, or even worse break through the cardboard. The cardboard may or may not get wet and soggy. The solution to fix a puncture or a soggy spot is to allow the boat to thoroughly dry out first. Depending on the severity of the soggy area it can take up to 2-3 weeks for the cardboard to completely dry.</p> <p>After the damaged area is dry simply tear off a piece of paper drywall tape. Adhere it to the affected area with contact cement. After the contact cement cures, paint the affected area with 3 coats of waterproof paint.</p>

Appendix I: OPTIONAL 2-Piece Hull

TASKS	EDUCATION NOTES
<p>OPTIONAL 2-Piece Hull (p.56-59)</p> <ul style="list-style-type: none"> ✓ Same instructions as the Hull Construction but using 2-pieces of cardboard spliced together. 	<p>This section may be useful to your educational situation based on the size of cardboard sheets you have to work with. It is a good idea to read this section to understand your options if needed.</p> <p><u>LEARNING OBJECTIVES:</u></p> <ul style="list-style-type: none"> ▪ Offer this as an option for your students to consider.

Appendix II: Frequently-Asked-Questions

TASKS	EDUCATION NOTES
<p>Based on 'The Cardboard Boat Book' website FAQs (p.60-61)</p> 	<p>What ideas do students have for other FAQs based on their experience making and using a cardboard Kayaker?</p> <p><u>LEARNING OBJECTIVES:</u></p> <ul style="list-style-type: none"> ▪ Engage students in a team discussion. Ensure all questions and concerns are addressed. ▪ I am always willing and available to answer questions. Feel free to email me at, dave@thecardboardboatbook.com. I will do my best to reply within 24 hours or less.

Appendix III: Web Resources

TASKS	EDUCATION NOTES
<p>Internet Resources for Locating Tools & Materials (p.62)</p> <ul style="list-style-type: none"> ✓ Cardboard Sheets ✓ Eco-Friendly Rubber Paints and Coatings ✓ Eco-Friendly Contact Cement ✓ Tools & Accessories 	<p>The use of the internet for research is a part of daily life. This section is intended to encourage student's research the possibilities, not necessarily a part of the curriculum.</p> <p><u>LEARNING OBJECTIVES:</u></p> <ul style="list-style-type: none"> ▪ An exercise in research.
<p>Cardboard Boats on the Web (p.62)</p> <ul style="list-style-type: none"> ✓ Cardboard Boat Events ✓ Cardboard Boat Races ✓ Cardboard Boat Regattas ✓ Cardboard Boat Designs 	<p>There are many organizations and educational institutions, both public and private, which hold annual cardboard boat races or regattas for events around the world. Encourage students to seek out unique and fun events that can be shared with others on their team. Can anyone find a design that is as unique and creative as the Kayaker? Structurally or aesthetically unique?</p>

Developing a Course Curriculum

The process for developing a curriculum for a class has dependencies on some variables. Variables include;

Do you have a need to align your curriculum with the Next Generation Science Standards (NGSS)?

- ✓ [Get to Know the Standards](#)
- ✓ [NGSS Example Bundles Available for Elementary, Middle, and High School](#)
- ✓ [Standards by Discipline Core Ideas](#)
 - [Download a PDF](#) of all standards grouped by Discipline Core Ideas (DCI)

Will this be a team based project or an individual project?

- ✓ Building a boat is a personal project as well as a team project. If possible the individual based project is most desirable. It is great to have the feeling of accomplishment having built the boats by yourself
- ✓ Team based projects are best when you have a limited amount of time to complete the project such as a corporate team building event.

Age range of students

- ✓ Need to develop an appropriate class for the age range being taught
- ✓ Elementary vs. Junior High vs. High School vs. College vs. University, etc.?
- ✓ Corporate team building event?

Student knowledge base at time of course

- ✓ Need to target the content to the level of knowledge students possess
- ✓ Is this an architecture class? An engineering class? Industrial design class? Other?
 - Determines what level and type of STEM content you want to address.

Duration of course

- ✓ How many weeks is the class scheduled for?
 - Determines how to pace the class.
- ✓ Team building weekend?

Physical location

- ✓ Are all the resources to build the boats available in your location?
- ✓ If not, how to improvise or acquire the resources?
- ✓ Student provided resources? Shared resources?

How to develop a Course Curriculum

- 1) Determine what variables your class will be constrained by.
- 2) Read through the tasks in each phase of the project and identify the topics you want to teach, and the topics you will leave to your students to work through on their own, or on a team.
- 3) Once you have identified the topics you want to teach you can then develop your instruction material for each topic. May include collaboration with instructors of classes you do not teach directly.
 - You may choose to integrate learning from another class into the boat project. Such as math or trigonometry.
- 4) Create a course outline based on the variables you have identified.
- 5) Expand on the outline for your teaching notes.
- 6) Develop a syllabus for your students based on the outline.
- 7) I recommend you build a boat for yourself in order to fine tune your course content.
- 8) You are ready to begin.

Sample Cardboard Boat Project Responsibility Matrix (RACI Diagram)

An industry standard RACI matrix identifies all the stakeholders in a project and what their roles are. For example, the educator is looked upon as a consultant for students when they have a question regarding the scope of the project. The educator also needs to remain informed of student progress and any blockers students may have during the duration of the project. Therefore the educator has the identifiers, **A/C/I** assigned to them for this project. Likewise, all participants/stakeholders in the project have RACI roles that need to be documented so everyone knows who to turn to for specific reasons.

LESSON: RACI diagrams are a standard Project Management collaboration tool. Have your students fill out a blank copy of this form for their team. It is a good way to ensure all students know what their role in the project is before they begin. It can also help mitigate any conflicts regarding responsibilities.

TASKS	RACI Matrix R = Responsible A = Accountable C = Consulted I = Informed	EDUCATOR	PROJECT MANAGER	PROJECT TEAMS	QUALITY CONTROL	TEST	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
1) Prerequisites to Building 'The Kayaker'											
1	What is a Cardboard Boat? (p.1)	A/C/I	R/C/I	C/I	I	I					
2	How Cardboard Boats Work (p.3)	A/C/I	R/C/I	C/I	I	I					
3	How to Get Started (p.5)	A/C/I	R/C/I	C/I	I	I					
4	Corrugated-Cardboard Required (p.6-7)	A/C/I	R/C/I	C/I	I	I					
5	Tools and Materials Required (p.8)	A/C/I	R/C/I	C/I	I	I					
6	How to Work with Cardboard (p.9)	A/C/I	R/C/I	C/I	I	I					
2) Chronological List of Tasks for Building 'The Kayaker'											
1	Overview of Building The Kayaker (p.12)	R/C/I	A/C/I	R/C/I	R/C/I	C/I					
2	STEP #1: Make the Hull (p.14-17)	R/C/I	A/C/I	R/C/I	R/C/I	C/I					
3	STEP #2 & #3: Make and Install the 2 Bulkheads in the ends of the Hull (p.18-19)	R/C/I	A/C/I	R/C/I	R/C/I	C/I					
4	STEP #4: Make and Install the Compression Beam inside the Hull (p.20-21)	R/C/I	A/C/I	R/C/I	R/C/I	C/I					
5	STEP #5 & #6: Make and Install the Stern and Bow to the ends of the Hull (p.22-39)	R/C/I	A/C/I	R/C/I	R/C/I	C/I					
6	STEP #7: Build and Install the Keel Beam on the underside of the Hull (p.40-42)	R/C/I	A/C/I	R/C/I	R/C/I	C/I					
3) Waterproofing 'The Kayaker'											
1	OPTIONAL: Installing 'Ding-Resistance' Material (p.44-45)	R/C/I	A/C/I	R/C/I	R/C/I	C/I					
2	STEP #8: Taping Your Kayaker in Preparation for Waterproofing (p.46-49)	R/C/I	A/C/I	R/C/I	R/C/I	C/I					
3	STEP #9: Waterproofing Your Kayaker (p.50)	R/C/I	A/C/I	R/C/I	R/C/I	C/I					