INTRODUCTION

I remember only a few things from fourth grade: the day I was chosen to work the slide projector (cutting-edge technology at the time), the day kids put glue on my seat, and the day we were asked to create a 3D map of our home, Long Island, New York, with clay, cardboard, and paint. The truth was, from the moment I first entered Mrs. Brush's classroom and saw the example of the 3D project hanging up, it's all I wanted to do in class. I was waiting excitedly for the day I would make one, and when the time came, I took a risk. I chose to lower the hills when they approached rivers because it made more sense to me, but it wasn't in the instructions and my classmates called me out on it. Thankfully, Mrs. Brush made it a teachable moment, shared that it was correct, and approved of my choice. It was an important moment that validated my independent thought as well as my art.

I've been an artist for as long as I can remember. It's always been a part of me, and when I think back on moments, I remember the images and the feelings. These days, I draw in a sketchbook and create with technology daily, and I still love to explore different subjects through art. When I introduce myself to others and they hear I'm an artist, they often ask how much work I sell, how well I draw, or if my work is exhibited in museums or galleries. While I've sold work, draw well, and am proud to have had my art exhibited in numerous museums, I believe none of those criteria make me, or anyone, a true artist. Being an artist is about being curious, examining the world around you, bringing a sense of creativity to what you do and make, and sometimes breaking the rules.

Overcoming the Fear (and Loathing)

Early on in my educational career, I didn't have much expertise in science, technology, or engineering, but I was always interested in learning more. Math, on the other hand, downright scared me. There are people who love math. I've met them. They just get it, or they find the order and the process appealing. I've also met math-phobic people who dread and loathe math class and often believe they will never be good at math. People in this group benefit tremendously when art is added to the learning process. I know because I was once one of those people.

Let me be clear: I don't want to bash math, because as an art educator for more than twenty years, I know there are also people who fear and loathe art and drawing the way I feared and loathed math. You might be one of those people and if you are, I believe I can help. When I have students who fear art, it's my job to show them that there is more to art than just drawing (though drawing is a skill anyone can learn if they have an open mind and put in time and effort) and, more importantly, that art is an act of personal creative expression that is valuable by itself regardless of the product. You don't need to be good at painting or singing or dancing or acting to enjoy it, learn from it, and benefit. Anyone who has ever tried karaoke or a paint night might know this personally because it is fun and expressive even if it is a train wreck. My advice: own your train wreck! As an artist, I have learned to harness my creativity, and by helping others do the same, I've seen it benefit their lives tremendously. My goal as an educator is always to share my knowledge and to help others cultivate their sense of creativity and curiosity—because once you connect that spark, it fuels the real power of learning.

Many academic subjects address misconceptions, fears, and resistance, but the interdisciplinary nature of STEAM makes it an especially powerful means to address these problems. The first step is identifying the problems and figuring out what they're stemming from. Often, they are irrational or based on false beliefs students may have. The next step is helping students open their minds and change their mindset. Carol Dweck, a psychologist at Stanford University, wrote a book on the topic entitled *Mindset: The New*

Psychology of Success that explains the difference between a "fixed mindset," in which people see their talents and abilities as set and static, and a "growth mindset," in which people believe their abilities can be improved through work and study. Dweck shares her research on how we can be held back by the way we think about our abilities and talents, and she notes that "becoming is better than being."

Students often see their failures or weaknesses as permanent, so they don't see the point in trying to improve upon them because it brings forth bad feelings. As a student who didn't naturally excel in math, I understand that reaction. Reflecting on those years, I believe my fear of math was intensified by the fears people around me had about it as well. It wasn't until many years later that I realized that math has a wide variety of aspects, many of which interest me. I learned to not take my early failure in math personally. It didn't define who I was, and once I understood that, I was able to progress and improve.

It is important for educators to understand this behavior of taking failure personally and to address it when it occurs with learners. When students see themselves as bad at something, they often widen the failure and feel bad about themselves in general, as if it's a permanent personality trait. It's hard, if not impossible, to motivate someone to do something that makes them feel bad about themselves, so it often helps to play to the learners' strengths at first to create positive associations. If students have skills or interests elsewhere, find a way to leverage those and connect them with the subject they have difficulty with. It's a process, but the work can be much easier if you remind students that failure is not permanent and if you explain the concept of having a growth mindset.

How to Use This Book

I offer this book to you as a simple, nonthreatening guide to exploring the world of STEM through art in fun, adaptable, meaningful, and engaging ways that allow for new insights and increased creativity. This book is made up of three parts: The first is dedicated to the fundamentals, giving an overview of elements that will help make the learning successful, safe,

and engaging. The second part consists of eighteen of my favorite STEAM projects that incorporate a wide variety of technology, from 3D printing to coding to cardboard and upcycling. The last part is focused on advanced STEAM concepts to expand the learning and grow your program.

Why Add Art to STEM?

"STEAM" education may seem like a hot trend now, but it's really a new acronym for an ancient educational idea that has been taught since teaching began. The idea of incorporating art into other subjects has been there all along; it's the lens through which we have viewed STEM because it's how this knowledge has been passed down over the ages. If we study the greatest STEM thinkers, we learn about their work through art, whether it's Marcus Vitruvius Pollio's analyses of architecture, Leonardo da Vinci's sketchbook illustrations, or Albert Einstein's writing on his theories.

In fact, regardless of the subject matter, we often learn through art: images, writing, music, speech, or movement. Art is what we as the human race pass on to the future, and it is how we understand our past. Art has always been there; the issue today is that it's not always easily accessible for teachers or students. This is in part because in our modern educational world with its system of segregated subject matter, art isn't always as valued or supported as STEM in our schools. It becomes an elite language that many don't speak, so it can get sidelined. Art also tends to intimidate people; it only takes one bad art experience to ruin the whole subject for some people and lead to a lifelong avoidance of art.

It may seem unnecessary to justify why art is beneficial to STEM, especially because you are reading this book, but I do encounter a great deal of resistance among some educators. I still regularly find myself in STEAM workshops that don't address art in any way but use the acronym because

it's become trendy. When I do see art included in STEAM projects, it's often shoehorned into lessons and not handled with respect, which is frustrating. But recognized experts such as Scratch creator Mitchel Resnick, technologist John Maeda, professor Seymour Papert, and author Sir Ken Robinson have all addressed the importance of creativity in education and the value of art in STEM learning. One of my goals is to offer you valuable tools to infuse art into STEM in meaningful ways that respect each of the component subjects. I've always found that learning new things is rewarding, and it certainly makes teaching much more interesting. As we learn about some of the different ways to infuse art into STEM learning, it's helpful to keep that perspective and have fun learning new art skills.

Infusing art into STEM might be intimidating but as you can see in some of my short videos, introducing it as a fun, creative challenge helps establish a positive mindset and builds excitement.

PART II

STEAM Projects and Technologies

In the following chapters, I'll share some of my favorite STEAM projects that I've used with students. I organized this section based on the technology used in the projects. Each chapter contains two projects, but there are additional projects and resources available on my website, timneedles.com.

CHAPTER 3

Classic Construction, Cardboard, and Upcycling

If you want to see creativity in action, hand a student some cardboard and glue and invite them to make something. As a kid, I used to turn cardboard boxes into rocket ships and fire engines, and as an adult, I'm inspiring others to do the same. These are the kind of projects that I post on Instagram and Twitter, and they get tons of likes because it's easy to see the creativity involved.

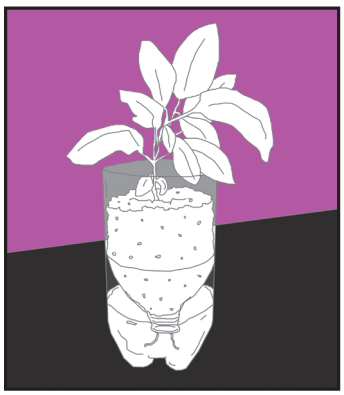
Classic cardboard and upcycling projects are fun, inexpensive, and easy to incorporate, regardless of your technical experience or background. If you're not familiar with the term "upcycling," it's like recycling, except rather than turning whatever is being discarded back into raw materials, we turn it instead into something new. There are an enormous number of cool, educational, and thought-provoking projects that are possible when you take materials that are no longer being used and redesign them into something with a new purpose. One of the greatest strengths of an upcycling project is that it not only inspires fun and engaging creative thinking but also models sustainable design.

As in any project, scale is also going to be a factor. It's easier to begin with something small then scale up as the students (and educators) become more comfortable with the process.

Upcycling depends on the materials you have available. When considering materials to work with, use the widest possible lens, because the best resources might literally be considered garbage by others.

I like to begin this work by presenting the materials and asking questions about them—it's necessary to think outside of the box to succeed in this arena. The artist Salvador Dalí was once served a lobster for dinner, and he pondered why he hadn't been served a telephone instead; yes, it seems absurd at first, but he then designed a lobster-telephone sculpture, one of his iconic works. What makes a lobster a lobster and a telephone a telephone? Why can't a car become an aquarium, or a train station a library? They can, of course, if we let go of our ideas about what they should be and reframe our thinking to imagine what they can be. Some of the best examples of upcycling can be found in urban areas, such as Chicago's Millennium Park, which was a parking garage that became one of the most popular public parks in the country, or the campus of Savannah College of Art and Design, where the school retrofitted many historic buildings to turn them into classrooms and workspaces for its students.

PROJECT



Upcycled Self-Watering Planter

This first project is to study, design, and create a self-watering planter. This can be done with a variety of different approaches, lengths of time based on the learners, and budgets, but all these variations should have no difficulty touching on all the STEAM disciplines.

A quick, popular, inexpensive approach is to use recycled materials such as a gallon soda container, which can be

cut and fairly easily reconfigured to allow the mechanics to work. A more detailed approach can teach learners the science and engineering behind the process, then ask them to create their own digital rendering of a design that can be 3D printed. It's possible to push the idea even further by being more specific with the resources and costs involved; for example, ask for the project to be affordable, sustainable, and capable of being used in a greenhouse in space or on another planet, meaning that it would also need to be easily shipped and reconstructed. Bring a sense of creativity to the learning and make the project work for you and your learners.

Project Details:

Overview: Design and create a self-watering or hydroponic planter out of recycled soda bottles.

Timeline: 45 minutes to 2 hours

Age/Skill Level: This project can be modified for any age and skill level

Extended Version: This project is for a self-watering planter, but for more advanced learners, you can assign the more difficult task of creating a true hydroponic planter that uses no soil. It uses water with a nutrient supplement, rather than the peat moss, and the roots can be supported by gravel or perlite.

Materials:

- paper and writing utensils, tablets, or computers to research, write, and draw with
- scissors
- markers
- clean, empty two-liter soda bottle
- recycled scrap piece of cotton (old socks work well)
- mixing bowl
- peat moss
- perlite
- fertilizer
- seeds (any type, but I'd start with lettuce)
- plastic wrap

STEAM: In this project, all the STEAM disciplines are represented equally.

Instructions:

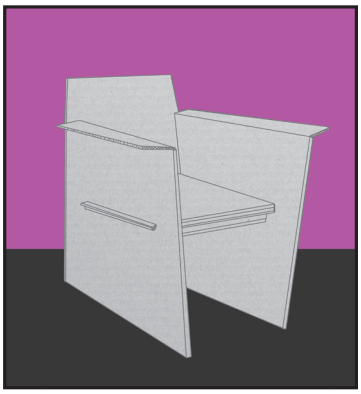
1. Begin by sharing the concept and history of self-watering or hydroponic planters and exploring its uses and value for space travel, farming, and urban planting.
2. Choose which seeds you are going to plant. For beginners, I suggest lettuce, herbs, cucumbers, and tomatoes.
3. Measure the empty soda container, remove any wrappers, and cut it in half at the midpoint, leaving the cap at one end and the bottom at the other.
4. Take the cap off the bottle. Cut down the piece of cloth and place half of it in the bottle and half of it out, so it blocks the hole.
5. Mix the perlite and peat moss evenly and add some fertilizer as directed. (If the perlite and peat moss are already fertilized, you can skip this step.)
6. Pour water into the bottom portion of the bottle.
7. Turn the top part of the bottle upside down and place it into the bottom half. Make sure the cotton is in the water, it should reach at least halfway into the water to create a flow upwards toward the seeds.
8. Add one cup of your perlite mixture to the top of the bottle. You don't want it seeping through the hole with the cotton, so make sure the hole is blocked before adding the perlite.
9. Plant the seeds in the mixture. They shouldn't be too deep, approximately the length of a pen cap (which is what I have students use to create the hole in the perlite mix).
10. Very lightly water the mixture. (We use a spray bottle.)
11. Cover the planter with plastic wrap and place it in the sunlight.
12. In a few days, seeds should begin to sprout. They can then be maintained the same as any other plant.
13. Reflect on the process. Once the learners comprehend the basic process, ask them to design a more creative version of the planter with the

information they've gained. You can add additional challenges, such as creating a hanging version for classroom windows or collaborating with others to scale up the planters for a large indoor farm in an urban environment.

14. Share your results on social media to encourage others to do their own planting.

Cardboard Chair Design

This project is more challenging, but it's a fantastic learning experience that touches on all the STEAM disciplines and results in some creative and innovative work. As you introduce your students to the process of designing and constructing a cardboard chair, there are some great examples to share from art and design museums, such as architect Frank Gehry's iconic cardboard chair design. The key to success is designing a chair that has both form and function: encourage your students to come up with a creative and interesting design that can also hold weight.



Project Details:

Overview: Collaboratively design and create a chair made from cardboard that can support the weight of a person.

Timeline: 2 to 6 hours

Age/Skill Level: This project is great for more advanced learners but can be modified for any age and skill level. Learners with limited skills might try to design the chair for a stuffed animal or toy.

Materials:

- paper and drawing supplies or computers to write with
- cardboard (various weights, strengths, and sizes recommended)
- glue and/or other adhesives
- computers or smartphones with digital design software or apps
- laser cutter (optional)

STEAM: In this project, all the STEAM disciplines are equally represented.

Instructions:

1. Begin by viewing a wide variety of chairs and researching how they are designed and work structurally.
2. Brainstorm and sketch potential ideas for your cardboard chair. It should be an appealing, comfortable design and structurally sound enough to hold weight.
3. Critique the designs and choose a few to create as scale models.
4. Draw out plans for the models with precise measurements, then create the scale model.
5. Test the models for structural integrity by adding set amounts of weights at intervals and writing down the findings.
6. Review the findings and choose a final chair design to create in full scale.
7. Collaborate to create the full-size cardboard chair design.
8. Photograph the final design and videotape the weight test on the full-scale model.
9. If the weight test shows it can support the weight of a person, take safety precautions and try to sit in the chair.
10. Share the documentation and reflect on the process and results.

The classics are classic for a reason, and there is no end to the great (and inexpensive) projects that you can create with cardboard. Check out timneedles.com for more project ideas, such as creating hexaflexagons, flexagons, flextangles, and other mathematical paper toys; designing trebuchets (for pumpkin chucking); designing and creating musical instruments; building gingerbread architecture; and making magazine vases from recycled paper.