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Harnessing the Power of Failure as a Catalyst for Innovation

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Introduction

For so long, the concept of "failure" has been a dirty word. In the game of life, there are winners and losers, and no one wants to be on the losing team. Those who have grown up learning (and believing) that "failure is not an option" and the goal is "winning at any cost" have dreaded and despised even the thought of failure. Yet, those who are true innovators have learned that not only is failure an option, but it is also a necessary step in the process of learning and growing and innovating. According to Jeanne Liedtka, "Most humans are driven by a fear of mistakes, so they focus more on preventing errors than on seizing opportunities. They opt for inaction rather than action when a choice risks failure. But there is no innovation without action..."[1] Therefore, it is imperative that educators begin to teach their students that failure is not final but is only a means to an end—there can be no innovation without failure. This will require a change in mindset that will allow students to see that failure is inevitable in the process of learning and should be welcomed as a teaching tool in their arsenal of skills.

Rationale

A. P. J. Abdul Kalam once said, "If you fail, never give up because F.A.I.L. means *First Attempt in Learning* and End is not the end, in fact E.N.D. means *Effort Never Dies*."[2] *First Attempt in Learning* should be the prevailing mantra for all learners because first attempt implies that there will be more attempts, hopefully many more. The fifth through eighth grade middle school students I teach at Tilden have struggled with persevering in the face of challenges and difficulties, especially when it comes to academics. They are more resilient in other arenas of their lives because they must be in order to survive in the hostile environment in which they live. They give up quickly at school because they are easily frustrated when faced with material outside of their experience, comfort zone, and perception of their own ability. This is particularly true when students do not see the relevance of what they are learning and how it will help them to be successful. Teaching students to reframe their thinking will open the door for them to begin to think outside the box and explore alternate options when they are not successful the first few times. The goal is for them to persist in trying to find solutions to problems by applying the tenets of Design Thinking and collaborative problem-solving to every

task they face. This curriculum unit will teach the principles and process of Design Thinking and provide opportunities for students to attempt challenges that will be met with failure at first for them to learn and grow. Students will learn that failure is to be expected when attempting anything in life, but that they must persevere and persist until they find a way to accomplish their goal. Students will also learn that while these challenges can be solved while working alone, working collaboratively will increase the likelihood that solutions will be reached more quickly and efficiently. This is how innovation is born.

So, what exactly is Design Thinking? According to Tim Brown, CEO of IDEO, "Design thinking is a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success."[3] It is a way of thinking that considers the needs of people as a central focus when designing or creating solutions for those needs. It also considers whether those solutions are accessible and sustainable. The five principles of design thinking are Empathize, Define, Ideate, Prototype, and Test. These principles were condensed to three E's—Empathy, Expansive Thinking, and Experimentation by Frederik G. Pferdt in his article, "Design thinking in 3 steps: How to Build a Culture of Innovation."[4] The three-step model basically condenses the steps of "Define, Ideate, and Prototype" into one step—Expansive Thinking. Even though this process may be thought of as a business or engineering model, all students are creative and can express their creativity in unique ways when given the opportunity to do so. No matter what subject a student is learning in school or what career they may be preparing for, a change in mindset will open many more doors for students to take ownership of their education and explore areas they may have never even considered.

This shift in thinking is equally important for all educators to embrace, even amidst the constraints and expectations of the traditional classroom. Both educators and students can benefit from creating the space for students to expand their horizons and look at every challenge that they face as an opportunity to discover something new. This curriculum will challenge students to tackle every activity with the understanding that everyone will not reach the same conclusions, that there is no *one* right answer, that each suggestion presents itself as a possibility, and that each time a new attempt is made, something new is learned, or discovered, or created. Every new thing learned forms the foundation for something else to be built upon, and if students can truly learn to engage in collaboration, rather than competition, they can reach their destinations sooner and perhaps discover something new in the process.

Because these concepts of Design Thinking are new to me, I am excited about creating a new learning experience for my students whereby they can all become explorers and creators. There is something very liberating about accomplishing a task that moments before seemed impossible to undertake, and when students begin to experience this feeling of success repeatedly, they become better innovators. A. J. Juliani has a few activities that he uses called "10 Design Thinking Activities to Get Your Group Creating."[5] These activities can be used with students of all ages and adults as well and this unit will explore a few of them. This unit will also compile many S.T.E.M. and problem-solving activities that will engage students and help them to develop a Design Thinking approach to every challenge they encounter. They will learn the principles of Design Thinking by "doing" them, by engaging in trial-and-error processes.

Purpose

My goal is to create a unit that is cross-curricular and that can address a wide range of standards, not just STEM standards so that more teachers can be encouraged to implement it in their classes. I believe that the more educators and students engage in Design Thinking, the better we can prepare our students to be innovators and creators that can address many of the problems that are faced by our world today. I have always believed that the solutions lie within the hearts and minds of my students. The key is in finding a way to unlock that creativity and unleash those solutions. This curriculum unit will be one of those keys.

Content Objectives

Anyone who has never failed at anything probably does not need this curriculum unit, but they have probably never attempted many things in life, and they certainly have not discovered or created anything new. The entire process of learning and growing involves trying and failing and trying again. And again. And again. No one seems to have a problem with the number of times a baby falls before learning to walk. It is expected that they will figure it out eventually and there is much encouragement to keep trying along the way. Each "baby" step is applauded and reinforces the idea that the baby should get back up each time they fall and try, try again.

However, as we get older, somewhere along the way, we begin to believe that we must succeed the first time (or very shortly thereafter) at everything we attempt. If we are met with failure, this translates to "we *are* a failure", and we think that perhaps we should try something else, or give up trying altogether. This is a shift in mindset from the baby who *can't* be kept down after a fall to the teenager or adult that *won't* get back up after a fall, disappointment or setback.

How or why this transition occurs is not nearly as important as the fact that we educators must address this shift if we are to help our students become successful in life. For far too long, the emphasis has been on the destination, and not the process, the end result and not the journey. Our students must come to understand that the learning and the growing and the discovering takes place along the way, and if the focus is only on reaching the destination, far too many give up on the process and never reach their desired destination or discover many ways to get there. We must learn to encourage and celebrate the process!

In high school, I was fortunate enough to have teachers who did this for me, especially in my math classes. I had always struggled with math, especially if I was taught that there was only one way to reach a solution and I needed to figure it out the "correct" way, or I did not understand the way it was taught. If given enough time, though, I could usually reach a solution, but I rarely followed the "pathway" taught in class. I wasn't trying to be difficult, but I needed to find a way that made sense to me. My process would often involve a lot of trial and error since many times I did not remember or understand how to use the formulas. Often, my teachers would admit that they had no idea how I had reached that conclusion, but since I consistently ended up with the correct answer, they encouraged me to keep doing whatever it was that I was doing because it was working.

One teacher gave me a very valuable key when I was struggling with maintaining my "D" average in geometry. I was frustrated because I did not understand why I had to "waste" time proving that one triangle

was congruent to another triangle when I could clearly *see* that they were congruent. This teacher (who was not my geometry teacher, by the way), explained to me that geometry was not about math—it was about a way of thinking. He explained that it was like the process a defense lawyer uses when trying to prove his or her client's innocence using the law, step by step. The lawyer had to learn the law and systematically apply it to their case, not simply declare something to be true. Suddenly, I understood what I was trying to do and *why* I was trying to do it and the process became like a game to me. I challenged myself to see how quickly I could prove a statement to be true or how many steps I could take to prove the same statement. My grade improved to an "A" almost overnight!

Even though I did not realize it at the time, I was learning that there are many ways to approach a problem and many pathways to a solution. I just had to persevere, even when something was very difficult. This lesson was about more than just figuring out how to solve a math problem—it was about learning how to solve life problems. No matter what subject an educator teaches, we must teach students how to think about failure differently. We must share our stories and the stories of others to help them see that failure is part of the process of learning and growing.

Jack Ma, the founder and executive chairman of the Alibaba Group said this very thing. "Our MBA programs teach a lot of success stories making people believe they can easily be successful. But when you share a lot of failure stories, people learn."[6]

Teach Students to Think About Failure Differently

Ed Catmull, former president of Pixar and Walt Disney Animation Studios once said, "We need to think about failure differently. I'm not the first to say that failure, when approached properly, can be an opportunity for growth. But the way most people interpret this assertion is that mistakes are a necessary evil. Mistakes aren't a necessary evil. They aren't evil at all. They are an inevitable consequence of doing something new (and, as such, should be seen as valuable; without them, we'd have no originality)." [7]

For our students to make the leap from being passive consumers to active creators and innovators, they must begin to embrace the process, which always involves making mistakes. If we are honest, we would have to admit that we don't really like even the thought of making mistakes. Most people don't, but if we could reframe our thinking to see that the process of trying and failing helps us to quickly eliminate the ideas that don't work so that we can get to the ones that will work, we could stop wasting time berating ourselves and channel that energy into exploring other directions.

In Carol Dweck's book, *Mindset: The New Psychology of Success,* she describes two different mindsets that determine whether a person can become successful. According to Dweck, a person either has a fixed mindset or a growth mindset. [8] For the person with the fixed mindset, it is all about the outcome, and if the outcome is undesired, the person considers themselves a failure. This person also believes that either they possess the skills necessary to accomplish the task or they do not. A person with a growth mindset realizes that while they may not have the skills initially, those skills can be learned through persistence. They understand that regardless of the outcome, there is value in what is learned in the process, and this motivates them to keep trying.[9]

Samantha McDuffee puts it this way: "Someone with a fixed mindset believes they are *entitled to success without much effort* and regards failure as a personal affront. When things go wrong, they are quick to blame, withdraw, lie, and even avoid future challenges or risk. Someone with a growth mindset sees failure as an

opportunity rather than an insult. When challenged, they are quick to reassess, adjust, and try again." [10]

"Helping students overcome the limitations of their mindsets is equally if not more important than acquiring content."[11] Educators must begin to reward students who are making multiple efforts toward reaching a goal, not simply the student who arrives first, learns the quickest, or earns the "A." When we do not do this, we create a culture where students do not learn from failure. In a race, if we only reward the person who crosses the finish line first, the other runners are not motivated to keep running. Between 23 and 25% of the students I teach every day are English Language Learners (ELLs). Many of them are brand new to the country and they are learning alongside their English-speaking classmates. One of the things that I am learning when dealing with my English Language Learners is that they are never simply trying to learn the content—they are learning the language, the technology, the body language, cultural cues, everything! To assess them on their acquisition of the content alone, without recognizing that they are reaching other equally important milestones along the way, does them a disservice. We must celebrate their other accomplishments as well. When we do this, we motivate them to continue to persevere and learn from their mistakes. Sometimes we learn that the only thing they lack is a way to communicate the knowledge they already bring to the table. When we provide multiple ways for them to express what they have learned (and are learning), we learn that they often bring a unique perspective that is invaluable to the process.

Learning from Mistakes and The Process of Innovation

In his article, "Why Failure is the Foundation of Innovation," Paul Schoemaker quotes James Joyce by stating "mistakes are our portals of discovery." He goes on to say that "they stimulate us to look beyond our narrow cocoon and encourage lateral thinking. They invite a fuller exploration of the periphery, that vast domain outside our area of focus where treasure may be hidden."[12] This lateral thinking is what Steven Johnson calls the "adjacent possible" in his book, *Where Good Ideas Come From.*[13]

Much of what we learn in life is learned through the process of trial and error. When we are learning to ride a bike, roller skate (or rollerblade), or swim, we are motivated by the desire to master the feat, so we keep trying until we accomplish our goal. If we do not, then we never learn. If our fear of falling or drowning is more powerful than our desire to learn, then we sit out life on the sidelines. If we are afraid to take risks, we fail to learn. And if we fail to learn, we will never make new discoveries, and we will never innovate.

According to Edward D. Hess in his article, "Creating an Innovation Culture: Accepting Failure as Necessary," "Failure is a necessary part of the innovation process because from failure comes learning, iteration, adaptation, and the building of new conceptual and physical models through an iterative learning process. Almost all innovations are the result of prior learning from failures." He defines innovation as "the result of iterative learning processes as well as environments that encourage experimentation, critical inquiry, critical debate, and accept failures as a necessary part of the process."[14]

Hess goes on to say that "Innovation requires a mindset that rejects the fear of failure and replaces that fear of failure with the joy of exploration and experimental learning."[15] This is also known as a growth mindset. So not only is failure a necessary part of learning, but it is also crucial in the process of innovation.

"Trying and failing at something gives you a significantly greater conceptual understanding of how to do something. It is this deep understanding that converts failure into future success."[16]

This quote by Kumar Mehta in his article, "How to Turn an Innovation Failure into a Success" resonates with

me because this is basically what one of my college professors explained to me when I was concerned about how long it was taking me to work through each week's assignment. Each set of questions always concluded with the question, "How long did it take you to complete this assignment?" I thought this was a rather odd question, but for me, the answer ranged from two hours to seventeen hours, with the average being about four or five hours. Although I reached the correct answers much of the time, I was deeply troubled because I knew that we would only have a maximum of two hours for an exam. "How could I communicate what I knew in only two hours?" I asked my professor. He explained to me that he knew that I had a much better understanding of the problems because I wrestled with them each week. The week that I spent seventeen hours working on the assignment was because I was stumped by one question that I wrestled and wrestled with all weekend. I was devastated when I finally had to conclude that I could not solve it, but I was the only student to get that question "correct" because I was the only student who did not have an answer. It turns out that the problem was unsolvable. We must teach our students that there is value in the struggle to learn, and that we learn more from material we struggle with than from that which comes easy to us.

Sochiro Honda, the founder of Honda said, "Many people dream of success. Success can only be achieved through repeated failure and introspection. Success represents the one percent of your work that results from the 99 percent that is called failure."[17] Introspection is a necessary part of the process. It is thinking about what did not work, why it did not work, and considering alternate options, and trying again. Repeating this process over and over is required.

Kevin White states in his blog, "Failures as the result from taking innovative risks should not be punished but rewarded. People must take risks to innovate, and people will not innovate if they fear failure."[18] When we translate this to education, the same is true for students (and teachers). Students must take risks to learn, and students will not learn if they fear failure. White goes on to say, "With experimentation and pushing the boundaries you can expect more failures than successes. The faster you can close that feedback loop the faster you can iterate and innovate." I believe that if we learn to expect more failure, we will be less disappointed by our failures and will be more motivated to keep trying new things.

One of the greatest inspirations for innovation is Thomas Edison and his development of the light bulb. His amazing attitude was evident when he stated, "I have not failed. I've just found 10,000 ways that won't work."[19] I believe that there are only two times when failure occurs—when nothing is learned from failure and when nothing is attempted.

Thomas J. Watson, Sr., the founder of IBM, gives closing words of encouragement for this section. "So, go ahead and make mistakes. Make all you can, because that's where you will find success: on the far side of failure."[20]

Innovations That Occurred by Mistake

It is interesting to note that there are many innovations that occurred purely by accident while the innovator was trying to accomplish something else. If the innovator was successful in their first attempt at innovation, there would be no interesting discoveries made along the way. Although these discoveries may have been unintended, our world would be lacking some incredible inventions. Let's look at a few of them.

Corn Flakes

Corn flakes were invented by John and Will Kellogg. They were trying to make a pot of boiled grain. They

accidentally left the pot on the stove for several days. The grain became hard and moldy. They figured out how to eliminate the mold and the corn flake was born.[21]

Chocolate Chip Cookies

Ruth Wakefield was the owner of the Toll House Inn. One day, she was trying to make chocolate cookies, but realized that she did not have baker's chocolate (unsweetened). So, she broke up a block of Nestle semi-sweet chocolate into small pieces, assuming that it would melt into the batter to create chocolate cookies. It did not, and the chocolate *chip* cookie was born.[22]

Ice Cream Cone

At the 1904 St. Louis World's Fair, an ice cream vendor ran out of dishes in which to serve his ice cream. The vendor next to him, Ernest A. Hamwi, came up with the idea to shape his waffles into cones to hold the ice cream and thus began the waffle cone.[23]

Potato Chips

George Crum (also known as George Speck) was a chef at the Moon Lake Lodge Resort in Saratoga Lake, New York in 1853. One of his customers kept complaining that his fried potatoes were too thick and mushy, and he kept sending them back. Crum became angry, sliced his potatoes paper thin as a joke, and then fried them. Surprisingly, his customer loved them, and this was the beginning of the potato chip, at least according to this version of the story! (There seem to be several versions of this story that all originate at the Moon Lake Lodge Resort.)[24] ,[25]

Slinky

Richard Jones, a naval engineer, was trying to make a meter to monitor power on naval ships. When he dropped a tension spring on the ground, he noticed that it kept bouncing from place to place. This is how he got the idea for the slinky.[26]

Post-it Notes

Spencer Silver worked as a researcher for 3M Laboratories. He was trying to make a strong adhesive. He created a weak adhesive that stuck to objects but could be pulled off without leaving a mark. Years later, another 3M researcher came to him with the idea to use the adhesive to create a bookmark that would stick to paper and save the page without damaging it. This eventually became the Post-it note.[27]

Play-Doh

Play-Doh was originally created by a company called Kutol Products to clean soot off wallpaper during the time when people heated their homes with coal. When people began to heat their homes with natural gas and electricity, there was no longer a need for this product. Joseph McVicker was trying to turn the company around when his sister-in-law, Kay Zufall, shared an article that she had read that claimed the product could be used for modeling projects. Since she was a preschool teacher, she took the product to school and allowed her students to play with it. She re-named the product "Play-Doh." The company was saved when it began to market its product as a children's toy, rather than a cleaning product.[28]

Silly Putty

James Wright was an engineer at General Electric during World War II. He was trying to make a rubber substitute out of silicon. While he was testing silicon oil, he added boric acid and discovered that it bounced. Although it did not work as a substitute for rubber, it made for a cool toy.[29]

Tea Bags

Two women requested the first patent for a "Tea Leaf Holder" made from mesh in 1901, but tea merchant, Thomas Sullivan began shipping his tea to his customers in silk pouches. His customers began using the silk pouches as tea bags even though this was not the intended use.[30]

X-ray Machine

Wilhelm Conrad Rontgen was a physicist in Germany. He was experimenting with vacuum tubes covered with cardboard when he noticed a glow coming from a nearby chemically coated screen. He called the rays "X-rays" because the origin was unknown. While he was playing around with the screen, he discovered that if he placed his hand in front of the screen, he could see past his skin to his bones.[31]

Implantable Pacemaker

1. An electrical engineer named John Hopps (Canada) was conducting research with hypothermia and was trying to use radio frequency heating to increase body temperature. During his experiment, he discovered that if a heart stopped beating because it cooled down, it could be restarted by artificial stimulation. This led to the development of the cardiac pacemaker, but this device was too large to be implanted.[32]

2. Wilson Greatbatch, an adjunct professor of engineering at the University of Buffalo was working on building equipment to record heart sounds. When he accidentally used the wrong transistor, he discovered that rather than recording sounds, the device began emitting an electrical pulse that mimicked the beat of the heart. He shared his invention with a surgeon named William Chardack at Buffalo's Veteran's Administration hospital and together they were able to control a dog's heartbeat and then a human's heartbeat. Greatbatch has been quoted as saying, "Failure is a learning experience, and the guy who has never failed has never done anything."[33]

This innovation is an example of two different people in two different countries working to resolve the same problem and creating the same innovation.

Microwave

Percy LeBaron Spencer was an engineer with the Raytheon Corporation. He was working on magnetrons—high-powered vacuum tubes that generate short radio waves called microwaves—when he accidentally discovered microwave cooking. When a chocolate bar in his pocket melted while he was working, he realized that this occurred because of the magnetrons. He placed popcorn inside the machine, and it popped. He later patented the microwave.[34]

Penicillin

Sir Alexander Fleming, a scientist threw away a contaminated petri dish he was working with. He later

discovered that the mold on this dish was dissolving all the bacteria around it. He decided to grow the mold and discovered that it contained a powerful antibiotic, penicillin.[35]

These innovations are evidence of what can happen when multiple attempts to accomplish a specific task produced an unintended effect or led to an interesting discovery. How many innovations do not exist because the innovator stopped short of discovering something new or gave up because of frustration?

Design Thinking Process

The Design Thinking Process is central to this curriculum unit. Students will not simply memorize the five steps to regurgitate on an exam but will learn them by using them over and over in each activity in this unit. This is a human-centered designed process, so the person(s) the technology is designed for is always at the center of the process. The process is not linear, and each step will be re-visited as often as necessary to accomplish the task (or discover something new along the way!)

Empathize

In this first step, there is an attempt to gain an empathic understanding of the problem from the perspective of the person who will be affected by the solution. Empathy is important because the person addressing the problem removes their personal assumptions from the process. This may involve immersing oneself into the situation to get a different perspective and observing from the inside. The process involves asking questions of all relevant parties in order to get a better understanding of what the real issue is so that the solution can be appropriate.

Define

A problem statement is generated during this step that focuses on what the person needs. It synthesizes all the information gathered in the first step. This statement may look like the following. “How might we help _____to _____?”

Ideate

This step involves brainstorming and generating ideas, thinking outside the box, and exploring all possibilities to find solutions to the problem statement that has been generated. These ideas should be non-judgmental, creative, and human-centered.

Prototype

This is the point where ideas are sketched out, diagrammed, visually represented, often in crude ways, but the point is to communicate the ideas. The prototype should be inexpensive, scaled down, and practical, but should represent the best possible solution to the problem.

Test

In this stage, the prototype is tried out, refined, and reiterated. Feedback is requested and used to make changes or improvements. More ideations may occur, more prototyping may be necessary, and the process may continue in an effort to reach the best solution.

Teaching Strategies

Close Read

Students will read the book, *Fantastic Failures: True Stories of How People Changed the World by Falling Down First* by Luke Reynolds. They will take note of innovations/discoveries that occurred by accident and quotes that are meaningful to them to add to their Google slides presentation.

Conduct Research/Create Google Slides Presentation (more innovations that occurred by mistake, failure/innovation quotes, etc.)

Students will conduct research to find more examples of innovations that occurred by accident and positive failure/innovation quotes. They will create a slides presentation that can be printed out as individual posters to display in the classroom and at home.

Hand's-on Learning/Collaboration/Building Models (arcade game-2 iterations, failure game)

Students will cooperatively build an arcade game in two iterations. The first iteration will involve no technology materials, such as cardboard, tape, plastic spoons, and a marble. The second iteration will build upon the first by adding robotics motors and sensors to add technology to their innovations to improve them.

The students will also build a "generic" version of The Failure Game or different version altogether that accomplishes the same goals of teaching students to persevere in the midst of difficulties and challenges. The original version is cost-prohibitive, and the students will use Design Thinking principles to design an affordable prototype that can be used in every classroom.

Design Thinking Process

Students will use some or all the steps of the Design Thinking process as they work to resolve a local problem, such as gun violence. The 8th grade students that I will be working with have already addressed the problem of gun violence in the city of Philadelphia when they were in 6th grade. We will address it again using the Design Thinking process. (Optional Extension: Students will work towards resolving the UN 2030 School challenge, where the students will choose a global problem from the UN's 2030 list such as poverty or hunger and map out a plan to address it using the five steps of the Design Thinking process.)

Diagramming Designs

Students will sketch out diagrams of how certain processes should work, such as their arcade or failure game design.

Coding/Robotics

Students will use coding and robotics to improve upon the arcade game they invented in iteration #1. This time, they will use motors and sensors from the Hummingbird Premium Kit and coding to animate their game with technology. This model will be more advanced than their previous design.

Classroom Activities

Read Fantastic Failures and Create a Collaborative Google Slides Presentation

Students will be placed in groups of 4-6 students, each with varying degrees of reading proficiencies. Each student will be given a graphic organizer and asked to read one chapter of the book. The other members of the class will each read a different chapter of the book.

- Each student will read their chapter independently. They will complete a main idea graphic organizer for their chapter. Then, each member of the group will take turns sharing the main ideas for their chapter with the other members of their group.
- Each group will then work together to compile their information into one Google Slides presentation that introduces the person(s) they learned about in their chapter and shares one meaningful quote from that chapter.
- Each slides presentation will have a title slide which includes the names of each person in their group, a table of contents slide, and two (2) slides for each chapter—one slide that introduces the person their chapter was about and the main ideas from their graphic organizer and one slide with the meaningful quote they selected. Each content slide will contain text and images.
- When all presentations have been completed, each group will share their slides presentation with the class. In this way, the class will learn about every chapter in the book, while only reading one chapter.
- Duration: This activity can be completed in 3-5 days:

    Day 1: Read chapter, complete graphic organizer, share main ideas with group
    Day 2: Share main ideas with group, begin working on group Google slides presentation with each student completing 2 slides that includes main ideas and meaningful quote with text and images
    Days 3-5: Groups will share slides presentations with class.

Maker Challenge: Build an Arcade Game (First version designed and built using no technology and the optional second version designed and built with the addition of a Hummingbird Robotics Kit.)

In this activity, teams will compete to design and build an arcade game using only four (4) items: cardboard, tape, plastic spoons, and a marble. In order to be successful in this challenge, teams must first sketch out the design of the game—what it will look like, how it will operate, etc. They will explain in writing how it will be played and what the objective will be. They will decide if the game will be scored and how points are obtained (or lost). Then teams must build a functioning game using only the supplies listed above. As they work together, they must determine if there are any other factors that must be decided in order for the challenge to be successful. The teacher will determine how much time is allotted to accomplish the task. The ultimate goal is to design and build a game that works.

Duration: This activity can be completed in 3 days:

Day 1: Teams will design, sketch out, and begin building game
Day 2: Continue building game, each team member tests the game, team makes improvements
Day 3: Complete the building of the game. (Additional days can be used to allow students to play the other teams' games.)

In the second (optional) iteration of this challenge, teams will improve their existing model by adding coding and robotics. This time, the following items will be added to the existing items: a laptop, a Hummingbird

Robotics kit, and glue (or hot glue). They will sketch out the new design, revise the original model to include motors and servos, and use their laptops to program the Hummingbird to operate the game. In order to complete this challenge, students must have prior knowledge of coding and robotics and must have access to one Hummingbird kit per team.

Duration: This extension can be completed in 3 days.

> Day 1: Teams will design, sketch, and begin building the animated version to include the use of motors from the Hummingbird kit. It may be possible to use a different type of robotics kit, but this is the one I have purchased for my students.
> Day 2: Continue building game, each team member tests the game, team makes improvements.
> Day 3: Complete the building of the game. (Additional days can be used to allow students to play the other teams' games. I would love to host a game day where students played each other's games.)

Play the Failure Game and/or Design Own Version of a Failure Toy

This activity will require the purchase of the Failure Toy kit created by Twenty One Toys (https://twentyonetoys.com/products/failure-toy-kit). This is an expensive investment, but K-12 educators receive a $100 discount, and I believe it is well worth it. (Note: I have had 2 kits funded through DonorsChoose to offset the cost. Each kit will accommodate 20 students.)

The concept involves teams of students competing to balance several oddly shaped wooden pieces on a wooden ring within a certain period of time. There are more than 20 ways to play the game, but all games require experimentation, taking risks, failure, trying again, learning from what does not work, relationship building skills, and working with a different team each round. For each round, a different student will win the "Failure Award" given to the student who has learned the most.

Each kit contains a guidebook with game scenarios, lessons, and discussion topics, in addition to the toy itself. This activity will allow students to learn by doing. They will experience failure many times, but will learn to take risks, adapt, and learn from their mistakes.

After students have experimented with the original Failure Toy, they will design and build their own version of a failure toy that follows the same basic principles, or different principles all together. If the purchase of the original Failure Toy is not an option, teachers may have their students figure out the basic principles for how the toy works and design their own version without having used the original version.

Duration: This activity will require a great amount of flexibility depending on the amount of time the teacher wants to devote to the activity. There are many different ways the game/toy can be used. After each round, the teams can be changed and/or the way the game is played can be played. (Disclaimer: The actual game/toy was not available during the writing of this unit, so I am aware that the explanations are somewhat vague.)

> Days 1-2: Explain how the game is played, form teams and allow 10-15 minutes per round. If teams are experiencing success very quickly, shorten the time for the next round. If none of the teams are experiencing success, add more time for the next round and do not create new teams until at least one team has been successful.
> Day 3: Discussion Questions/Reflection on what has been learned
> Day 4: Begin the process of designing a similar or altogether different version of the toy. The teams will

sketch out the prototype, determine what is needed to build the toy and brainstorm about where/how to acquire what is needed.
Days 5-7: Gather items needed to begin construction and begin to build the prototype. Test the prototype, make adjustments, test again. Ideally, I would like for students to be able to demonstrate their prototypes in other classes, and with other students, get feedback about what works/does not work, and improve upon the design.

Innovating for Change

This activity will follow the Design Thinking process to develop solutions for a real-world problem. I had planned to use the United Nations 2030 goals to have students design a solution to end world hunger or poverty. However, with the rise in gun violence in our city and in our nation, I decided to bring the problem closer to home. The eighth graders that I will work with this year participated in the Young Heroes Program when they were in sixth grade. They chose gun violence in their city as the social issue they wanted to address in their action project. I would like to take that project a step further and have them address it again from a different angle.

This time, students will use the questions that came directly from a lecture in "Human-Centered Design of Biotechnology" taught by Professor Anjelica Gonzalez (with her permission) at Yale University this summer to work through the process. It will be modified slightly for use with middle school students.

Goal: Innovating for an End to Gun Violence

Objective: Students will work in teams to design a solution to address the gun violence in Philadelphia, using the following framework to guide their thinking during the process:

Empathizing

- Who do you interview? (Who do you talk to begin to understand why gun violence is a major problem in Philadelphia? Victims of gun violence? Perpetrators? Community leaders?)
- Can you understand their perspective?
- What are some underlying problems that are addressable?

Ideating

- Where and with whom will you ideate?
- Who can we collaborate with?
- What experts do we need?

Define

- Develop a focus and a targeted problem statement, i.e., "How can we help _____ to _____?
- Is the hypothesis multiphasic, i.e., are there multiple interpretations or angles to the problem statement?

Experimentation/Prototyping

- Can this be done simply and in a timely fashion?

- What are the early limitations to development?

Testing

- Who do you go to for feedback?
- What is the extent of the feedback that is necessary?
- Is there a sample size target?
- Are there specific outcomes or metrics that you expect from each step of testing?

Duration: This activity can be completed in 5 days:

> Day 1: Walk the students (whole group) through the Design Thinking questions using another problem as a model. This may be a problem that the students choose.
> Day 2: Empathizing and Ideating—In small groups, students will brainstorm answers to the questions above. Each member of the group will be expected to participate and contribute to the discussion. Notes will be taken because they will be referred to throughout the process. Students should note the pros and cons of each suggestion.
> Day 3: Define and Experimentation/Prototyping—Students will work towards developing a targeted problem statement and determining if the problem must be addressed in multiple stages. Can a prototype be designed to address this problem?
> Day 4: Testing—How do we get feedback about our prototype? Who would we ask? How do we know if our prototype is effective in addressing the problem?
> Day 5: Sharing of solutions and reflection—Were the groups able to work through all the steps? What were some of the obstacles? Was the process challenging? How so? What could be done differently?

NOTE: The purpose of this activity is to address the standards and to teach the students how to navigate through the process. It is not necessarily intended to be graded in the traditional sense, but during the discussions and prototyping, the teacher will be looking for evidence of students working through the process collaboratively, listening, sharing ideas, taking notes, and evaluating themselves. It is expected that the process will be re-visited over and over throughout the course.

Appendix- Implementing District Standards

CCSS.ELA-LITERACY.RI.8.2 Determine a central idea of a text and analyze its development over the course of the text, including its relationship to supporting ideas; provide an objective summary of the text.

CC.1.2.8. B Cite the textual evidence that most strongly supports an analysis of what the text says explicitly as well as inferences, conclusions, and/or generalizations drawn from the text.

Students will read Fantastic Failures to determine the central ideas and provide supporting evidence. They will perform a sort of jigsaw where each student reads a portion of the book, synthesizes the information with what others in their group have read, so that they can work collaboratively on a project. This will provide the background information that supports the fact many successful people, whose names with which they are familiar, have backstories of repeated failures before they became successful.

ISTE Standard 3: Knowledge Constructor: Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts and make meaningful learning experiences for themselves and others.

15.4.8.K**:** Create a multimedia project using student-created digital media.

Students will create a Google Slides presentation using information obtained from the book Fantastic Failures. They will compile the information they each have read, create a presentation that follows a rubric, and includes text, images, transitions, and animations.

CC.1.4.8. V Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Students may also conduct research to learn about other innovations that were discovered or created by accident and create a second Google Slides presentation. This will allow students to create their own version of a Fantastic Failures presentation that is meaningful to them.

Science and Engineering Practices Based on Appendix F of the Next Generation Science Standards © 2013 Achieve, Inc. on behalf of the 26 NGSS Lead States.

Constructing Explanations and Designing Solutions:

Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.

Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and retesting.

These standards will be implemented when students are designing, building, and improving upon the arcade game. They will develop a design, construct it, test it, revise it, retest it, and get feedback about the efficiency of their and how to improve it.

These standards will also be addressed when students are playing with the Failure Toy and/or designing their own version of the Failure Toy.

These standards will also be addressed when using the principles and process of Design Thinking to develop a solution to the problem of gun violence in Philadelphia.

Teacher Resources

In addition to all of the sources listed in the bibliography, the following are additional resources that may be used:

Meyers, Morton A., *Happy Accidents: Serendipity in Modern Medical Breakthroughs (Arcade Publishing, 2007)*

This is a fascinating book subtitled, “When Scientists Find What They are Not Looking For” and basically deals with medical discoveries that occurred by accident.

Schoemaker, Paul J. H., *Brilliant Mistakes: Finding Success on the Far Side of Failure* (Wharton School Press, 2011)

This book is very similar to the above book, but it focuses more on business innovations.

Spencer, John, and Juliani, A.J. *Empower: What Happens When Students Own Their Learning*

Spencer, John, and Juliani, A.J. *Launch: Using Design Thinking to Boost Creativity and Bring Out the Maker in Every Student*

Spencer, John, and Juliani, A.J. *Vintage Innovation: Leveraging Retro Tools and Classic Ideas to Design Deeper Learning Experiences*

I did not read these three books, but they seem to tie in perfectly with this unit. I would recommend them as additional resources. I used Juliani’s list of Design Thinking activities.

https://twentyonetoys.com/blogs/learning-from-failure/fail-first-attempt-in-learning-why-failure-key-innovation

This is the website that introduces the Empathy Game and the Failure Games and how they can be used to teach students to show more empathy and to learn from failure. This site also includes a link to where they games can be purchased.

https://blog.hypeinnovation.com/why-failure-is-an-essential-component-of-a-strong-innovation-strategy

https://www.gsb.stanford.edu/insights/baba-shiv-why-failure-drives-innovation

These are two more articles about how failure drives innovation that I pulled quotes from but did not end up using because they were very similar to others I chose.

https://uxplanet.org/principles-of-design-thinking-stages-of-design-thinking-b2cc219063ac

This is an article about the principles of design thinking.

Yeager, D. S., & Dweck, C. S. (2012). Mindsets that promote resilience: when students believe that personal characteristics can be developed. Educational Psychologist, 47(4), 302-314.

This is another article about the impact of mindset shifts in helping students to become resilient.

Fantastic Failures Graphic Organizer

Name_____ Date_____

Fantastic Failures Graphic Organizer

Chapter: _____

Main Idea #1: _____

_____

_____

Main Idea #2:

_____

_____

Main Idea #3:

_____

_____

Main Idea #4:

_____

_____

Meaningful Quote:

_____

_____

Student Resources

Reynolds, Luke, *Fantastic Failures: True Stories of People Who Changed the World by Falling Down First*

This book was written for middle school students to share the backstories of so many people that we usually only see as successful. Their journey is shared so students can see all the many times they failed before they became successful.

Reynolds, Luke, *Even More Fantastic Failures: True Stories of People Who Changed the World by Falling Down First*

This is the sequel to the first book with more stories. This book is optional or may be used instead of the first book.

Annotated Bibliography

"Cardiac Pacemakers," *animalresearch.com*

https://www.animalresearch.info/en/medical-advances/medical-discovery-timeline/cardiac-pacemakers/

This website explores the history of the cardiac pacemaker with a brief video and brief explanations of two

engineers who were working on them in two different countries around the same time.

Bhattacharya, Rohit, “11 of the Most Famous Accidental Inventions Ever,” https://www.scoopwhoop.com/inothernews/invented-by-accident/

This article is about eleven famous accidental inventions.

Daugherty, Greg, “Who Invented the Potato Chip?” *History,* February 3, 2021,

https://www.history.com/news/who-invented-potato-chip-saratoga

This article sheds more light on the conflicting stories about several people who claimed credit for inventing the potato chip.

Durst, Carolin, “How Failure Impacts Innovation,” *Innovation Culture (blog),* May 14, 2018, https://www.itonics-innovation.com/blog/how-failure-does-or-does-not-impact-innovation/

This blog encourages people to stop making excuses for failure and find a way to innovate.

Dweck, Carol, *Mindset: The New Psychology of Success* (New York: Ballantine Books, 2008), 6, 66.

This book explains the difference between a fixed mindset and a growth mindset and encourages a move toward the growth mindset.

Greenwald, Morgan “30 Life-Changing Inventions That Were Totally Accidental,” *BestLife,*

September 25, 2018, https://bestlifeonline.com/accidental-inventions/

This article lists 30 accidental inventions and how they were created.

Hess, Edward, “Creating an Innovation Culture: Accepting Failure as Necessary,” *Forbes,* June 20, 2012, https://www.forbes.com/sites/darden/2012/06/20/creating-an-innovation-culture-accepting-failure-is-necessary/?sh=5ade9210754e

This is a brief article that supports the fact that entrepreneurs and technology-disrupting companies recognize the necessity of failure in coming up with novel ideas.

Johnson, Steven, *Where Good Ideas Come From* (New York: Riverhead Books, 2010), 25-42.

This book provided the introduction to innovative thinking for the course I took at Yale, “Human-Centered Design of Biotechnology” taught by Professor Anjelica Gonzales.

Juliani, A.J., “10 Design Thinking Activities to Get Your Group Creating,” http://ajjuliani.com/design-thinking-activities/

This website provides design thinking activities that can be used in the classroom.

Krueger, Alyson, “15 Life-Changing Inventions That Were Created by Mistake,” *Insider,* November 16, 2010, https://www.businessinsider.com/these-10-inventions-were-made-by-mistake-2010-11

This article provided more examples of inventions that were created by mistake.

Liedtka, Jeanne, “Why Design Thinking Works,” *Harvard Business Review* (2018), 72.

This article explains why design thinking works.

McDuffee, Samantha, “Innovation in Companies: Reward Failure & Get Results,” TeamBonding (blog), September 13, 2019.

https://www.teambonding.com/innovation-in-companies-reward-failure/

This article provides a different perspective on how companies should respond to failure by suggesting that they should reward failure. It increases the sharing of ideas and speeds up the process of innovation.

Mehta, Kumar, “How to Turn an Innovation Failure into a Success,” *Forbes,* March 11, 2019,

https://www.forbes.com/sites/kmehta/2019/03/11/how-to-turn-an-innovation-failure-into-success/?sh=5a19e39f3fc7

This article gives advice about how to convert an innovation failure into a success.

Pferdt, Frederik G., “Design thinking in 3 steps: How to build a culture of innovation,” *Think with Google*, October 2019,

https://www.thinkwithgoogle.com/future-of-marketing/creativity/design-thinking-principles/

Google provides a tutorial on how to increase the capacity to innovate from a business perspective by focusing on 3 design thinking principles-empathy, expansive thinking, and experimentation.

Roberson, Sam, “Developing Student Success Through Persistence: Teaching More Than Content,” *Education.*141, no. 2 (2020):83+ *Gale in Context: Biography* (accessed July 14, 2021). https://link.gale.com/apps/doc/A664798150/BIC?u=upenn_main&sid=summon&xid=9bff7919

This article stresses the importance of helping to change student mindsets so that they can persevere, which is as important as learning content.

Shoemaker, Paul, “Why Failure is the Foundation of Innovation,” *Inc,* May 13, 2012,

https://www.inc.com/paul-schoemaker/brilliant-failures/why-failure-is-the-foundation-of-innovation.html

This article re-iterates the need to welcome and learn from mistakes.

Sloane, Paul, “Failure is the Mother of Invention,” *Innovation Management*, October 13, 2004

https://innovationmanagement.se/2004/10/13/failure-is-the-mother-of-innovation/

This editorial demonstrates how failures can actually lead to new innovations.

Wardle, Duncan, “Fail, Fail, and Fail Again—The Secret to Innovation,” January 3, 2020, https://duncanwardle.com/why-failure-is-the-secret-to-innovation/

This article provides more support for why making mistakes often leads to new discoveries.

White, Kevin, "Innovation and Failure: Learning the Route to Success," *IDEASCALE* (blog), https://ideascale.com/learning-from-failure/

This is one final article which states what we have been saying all along about the relationship between failure and innovation.

Endnotes

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[1] Jeanne Liedtka, "Why Design Thinking Works," *Harvard Business Review* (2018), 72.

[2] A. P. J. Abdul Kalam was a former President of India and a world renown Space Scientist. One of his goals was to encourage students in India to pursue a career in Space Technology. www.abdulkalam.com

[3] IDEO is a global design company. www.ideo.com

[4] Frederik G. Pferdt, "Design thinking in 3 steps: How to build a culture of innovation," *Think with Google*, October 2019, https://www.thinkwithgoogle.com/future-of-marketing/creativity/design-thinking-principles/

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[6] Carolin Durst, "How Failure Impacts Innovation," *Innovation Culture (blog),* May 14, 2018, https://www.itonics-innovation.com/blog/how-failure-does-or-does-not-impact-innovation/

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[18] Kevin White, “Innovation and Failure: Learning the Route to Success,” IDEASCALE blog https://ideascale.com/learning-from-failure/

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