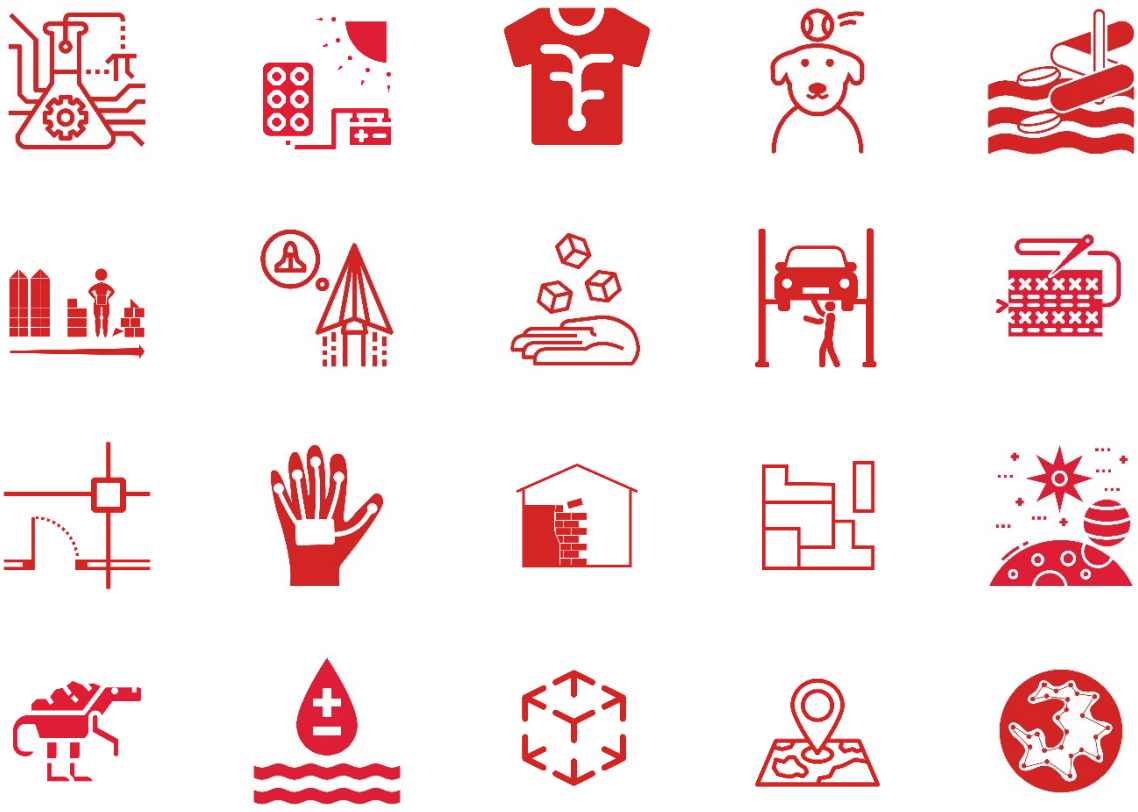
White Space Opportunities for STEM & STEAM Toys



Prepared for The Toy Association
July 2019

the toy association

prodigyworks

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Continued…

EXECUTIVE SUMMARY

ProdigyWorks, an innovation firm working with diverse multidiscipline teams of high-IQ and creative innovators and problem solvers, has recently taken a long-term view of *The Future Toy Consumer and Ecosystem* and a closer-in look at *Toy Retail and Manufacturing.*

Now with the Toy Association's in-depth explorations of toys for STEM and STEAM — *Decoding STEM/STEAM* and *STEM/STEAM Formula for Success* as reference points, a completely new Prodigies team of STEM educators, creative parents, innovators, entrepreneurs, artists, engineers, scientists, and toy enthusiasts collaborated to explore potential gaps and uncover new opportunities to bring STEM and STEAM to toys and play in new ways.

The focus is on what can be devised, designed, manufactured, and played within the next one to two years, but adaptability for the future is also an element of many of the ideas.

The Toy Association selected eight platforms, some of which include *Discovery and Imagination*, *Design and Build*, *Toys in Context in New Spaces*, and *Wearables*. The platforms also encompass ideas related to STEM principles, skills for job and career, integration with the Internet of Things/Toys, getting outdoors, and alternatives to passive "screen time."

Review by STEM Teachers

Two outstanding STEM educators reviewed more than 70 ideas under the selected platforms to narrow the list to 40 concepts.

- *K-12 STEM Outreach Manager* — a microbiologist, mentor to early-career scientific researchers, the recipient of several top national STEM teaching awards, and a classically trained pianist.
- *STEM and Science Supervisor* for grades 6-12 — creator of new Virtual Reality tools for teaching geology, as well as a maker, builder, brewer, baker, and avid family road tripper.

The experts considered the connections with NGSS *(Next Generation Science Standards)* and added options to selected concepts to improve STEM and STEAM learning, safety, and play value. They made some connections across platforms to describe exciting new opportunities. Their notes and recommendations are included with many of the ideas.

Concepts Can Take Many Paths from the Starting Point

The 40 concepts and ideas for learning and play presented in this document are not detailed plans tied to any particular company or current product line and should be open for a broad range of Toy Association members to explore and interpret for their own distinctive lines of STEM and STEAM toys. We hope that the concepts and resources will lead to some exciting conversations among your stakeholders.

Key Resources

In support of the selected concepts, we have provided two resource pages at the front of the Appendix.

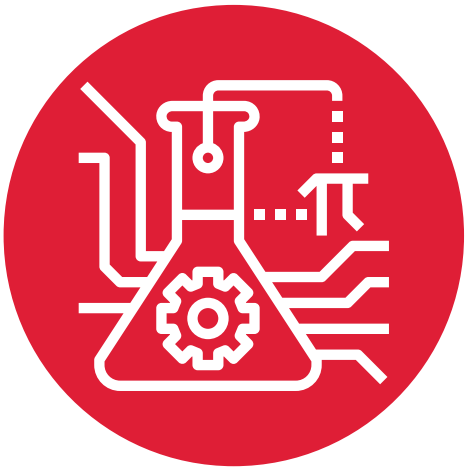
Next Generation Science Standards

Several of the comments from our STEM teachers refer to aspects of NGSS – *Next Generation Science Standards* for grades K-12. Here are recommended resources to learn more about NGSS and Three-Dimensional Learning (Practices, Crosscutting Concepts, and Disciplinary Core Ideas), which may inform and inspire the creation and development of STEM toys.

STEM and STEAM Wearables & Smart Textiles

This is a linked list of design partners, thought leaders, and relevant research. Although the focus in this list is on Wearables, there are novel materials and technology resources that apply to other aspects of STEM and STEAM toy design and manufacturing.

STEM PRINCIPLES



- Show the Flow of Electricity
- Smart Toys Connect with Weather & Climate
- Easy-Bake Chemist
- Water Play
- VR Chemistry World

The platform of STEM Principles is a group of toys and play experiences to introduce and expand knowledge of principles of Science, Technology, Engineering, and Mathematics.

The example ideas for toys and product lines described in this section and in the Appendix go beyond standard experiment kits and can be interpreted and developed in a variety of physical and virtual formats.

[1] SHOW THE FLOW OF ELECTRICITY

Often, designing things with electricity or electronics can be challenging for beginners because you can't see the electricity flowing or voltage.

This could be an entire line of electronic toys available in stores, online or by subscription—a series of simulated electrical/electronic components where you could connect wires that would light up to demonstrate voltage and current flow. The line would present greater difficulty in increments.

A completed module becomes a building block for the next module and builds on the skills and knowledge gained. Start with the basics; current, circuits (series and parallel), build a battery and move into more advanced areas with capacitors, resistors, and more.

The line of Show the Flow of Electricity toys is STEM all the way and is open-ended as the user grows in knowledge and skill.

Comments from STEM Teachers - Show the Flow of Electricity

- This is a great concept because it allows for building, thinking, and creativity. Best of all, it allows the user to see the unseen, how electricity flows. The visualization aspect is great; voltages can diminish when split up or run through long lengths of wire, and to be able to see it is excellent. Gain the basic knowledge from the introductory set and then build and design more involved pieces. Thumbs up!
- Related add-on kits could include electromagnets and levitating trains!
- In a way, it seems like an enhancement of *Snap Circuits*, which I like and teach with.

[2] SMART TOYS CONNECT WITH THE WEATHER & CLIMATE

The seasons change in many places, which can lead to the shelving of some favorite toys until the season comes back around again.

What if a line of toys could adapt and even change the play experience, without changing its STEM/STEAM core identity? It needn't be an exclusively outdoor toy or even an outdoor toy at all. It simply recognizes that the seasonal change has arrived and the fun changes with it. It's easy to think of a toy that thrills on Christmas morning and is forgotten by Spring. However, with this new line of toys, by the first day of spring, something has changed, and the same toy can provide new fun, challenges, discoveries, and capabilities.

This would require at least some level of technology. Toys like this could be associated with weather news or the Weather Channel. STEM/STEAM elements can be easily incorporated and, more importantly, stay fresh and surprising long past the point where other toys have lost kids' interest.

Comments from STEM Teachers – Smart Toys Connect

- The benefit here is that this type of toy would have versatility and remain interesting to play with. What it could be is open-ended, and fits with toys that have the potential to adapt to promote expanded play and creativity.
- Climate is an area of need with potential for expansion. Weather patterns and climate are an area of needed education. There has been a considerable decrease in the number of Environmental Science teachers, courses, and college degrees, even though earth and space science represents nearly one third of the Next Generation Science Standards (NGSS).

(See useful resources on the NGSS page in the Appendix of this document.)

[3] EASY-BAKE CHEMIST

This may seem like an adaptation of a classic toy, but it is really changing a mindset about an everyday enjoyable activity. Make chemistry the focus in toys for baking, instead of the sweet treats.

Chemistry kits would include all necessary components to understand how reactions are not random. They could include a tie-in with interactive videos, or internet digital content for comparisons and more discovery. There could be a baking contest that is judged by the scientific properties of the product, not just the appearance or flavor. As the child learns, more difficult baking challenges could be offered to keep their interest.

Anyone who has failed at baking a yeast bread knows that baking is chemistry! A toy line, either technical or not, can promote the chemistry point of view, not the result. It would concentrate on the process and allow for failure as a learning tool. This idea meets the criteria of fun and engaging, gender neutral and inclusiveness and relating to the real world. It creates a new space of educating students to place scientific objectives at the forefront of their minds while doing everyday things. It sparks curiosity!

Comments from STEM Teachers – Easy Bake Chemist

Precision and accuracy are always a starting point for every science class and an underlying skill for scientific pursuits. I'm a baker, brewer and science teacher, and see the connections. The Easy-Bake Chemistry set could include materials for experiments that emphasize the particular reactions that happen in baking.

Maybe there are corresponding "double sets" of materials – one set is just for fiddling with amounts and watching what happens, and the other is for an edible recipe that uses the same science. I was thinking about sourdough starter. That is a total science experiment that requires monitoring and care. If it doesn't work, start again. The bonus of a successful experiment is that you can eat a nice loaf of sourdough bread, a possible kit in the product line.

[4] WATER PLAY

A line of STEM toys and add-on kits for use with water in the kitchen sink, with a hose, or a swimming pool helps kids learn science and math principles while they're having fun.

Water Play toys could be offered as a series of kits with a focus on concepts such as properties of water (adhesion, cohesion, surface tension, capillary action); flotation with different buoyancy; volume measurements with cups, cylinders, shapes; fluid flow with pipes and pumps, water wheels, sluices, gears, and pulleys. This line of toys with various levels of complexity would invite open-ended and outdoor play. Each set should include a guide for parents to help them tie the water play experiences to the discovery and exploration of STEM concepts.

Kids love water parks, and they could extend their STEM learning through building toy waterslides, which they could design and assemble with tracks, tunnels, and slide pieces. They can also use a combination of gravity flow and water jets (with hose attachments), and then have fun testing outside with water and some kind of objects or "riders" to send down the slide. Incorporate spouts to float balls or launch things. A little Bernoulli's principle fun is always a good time!

Comments from STEM Teachers – Water Play

- The core idea here provides a unique opportunity to incorporate learning about geometric shapes/volume/water pressure. Printing equations, volumetric guides, and angles on the back side of pieces will promote passive learning of math. Build in challenges for the player to create their own structures.
- Let's go BIGGER! All of the play items are mounted to suction cups or magnets or have the ability to switch. It's outside with the garden hose, and the play items can be mounted on garage doors, sliding doors, sides of the house, car, van, outside the above ground pool, and anywhere else they will stick.

[5] VR CHEMISTRY WORLD

Chemistry starts with the study of things too small to see, and could make an exciting and fun virtual world to walk around in and manipulate!

A line of virtual reality toys and apps takes kids into a chemical world filled with atoms and molecules that are huge and floating around them. Kids could manipulate these items and learn about chemical bonding as they see which things have charges that make them want to pull together and combine into larger molecules or compounds—and learn about their properties too. Kids could grab and combine hydrogen and oxygen atoms to form water right in front of their eyes, and see it pour right out of their hands!

Perhaps instead of a single item, the molecules are physical, but they are programmed with their atomic properties to interact virtually. Alternatively, it could be represented by periodic table pieces instead of the molecules due to limitations of atomic size.

This line would allow for fresh, fun, and amazing experiences, along with lots of learning about chemistry in a safe and engaging setting. It combines open-ended fun with learning opportunities and would be relevant now and into the future.

Comment from STEM Teacher – VR Chemistry World

- The concept and platform seem like a one-player game as described. Making it for multiple players would be more interactive and fun.
- Here are links to a couple of relevant resources:
  https://www.rcsb.org/ligand/PBD (Protein Data Bank)
  https://chemagic.org/molecules/amini.html (Virtual Molecular Kit)

WEARABLES AND SMART TEXTILES

- CORE IDEA 1: STEM Sleeve
- An Expandable Line of "Watch" Wearables
- Make Large Scale Art Patterns Outdoors

It's exciting to explore the potential intersection of wearable clothing and devices with play and toys because it can leverage the developments in smart textiles and wearables and incorporate the element of fun in learning.

Wearables can take STEM and STEAM toys to new retail spaces beyond the toy store or "toy aisle" of a mass merchandiser. We can imagine wearables using smart fabrics, formats, and designs beyond the expected clothing elements of shirts or jackets.

[6] CORE IDEA: STEM SLEEVE

Seeing things as they exist in their natural habitat is a more effective learning method than just reading or watching a video about plants and insects. It's also fun and great exercise to go for a walk.

When walking in a park, on a trail, or in the woods, the user could wear a GPS-enhanced STEM Sleeve, which has a screen and a magnifying glass to enlarge the view of tiny insects and leaves, and a database would identify what they are. (The app *Leafsnap*, for example, connects with a database compiled by the Smithsonian and two universities.)

To add a sense of purposeful play or adventure, and based on the geographic location of the player, challenges can be sent out to find specific organisms native/endemic to that area. This could even be linked to citizen science challenges to find and document invasive species.

Comments from STEM Teacher – STEM Sleeve

- The sleeve can have interchangeable modules and programs to adapt to different environments—ocean/beach/lake/river, forest, desert. STEM Sleeve + modules can be offered at museum, zoo and national park gift shops, and online. Buy the appropriate module for where you are visiting to attach to your existing sleeve to explore.
- The STEM Sleeve is a Core Idea, and would work well with several of the ideas in this report, such as [7] *Watch Wearables*, *[24] Limnology Kits*, *[25] Sun Play at Parks*, and more.

(See Background & Resources for STEM/STEAM Wearables: Design Partners, Thought Leaders and Relevant Research in the Appendix for links to information about topics such as smart textiles, smart magnets, soft circuits, and more.)

[7] AN EXPANDABLE LINE OF "WATCH" WEARABLES

A versatile modular STEM platform on the wrist can be a kid's convenient companion in learning about, exploring, and recording observations about many subjects of interest.

This can be a game platform and/or a scientific platform that lets you switch the face to another module which allows the user to have multiple interfaces for different tasks or games.

A weather station "face" could be used to take measurements that can be observed over time, shared with a community, or downloaded for experimentation. Another module could help explore astronomy and star charts. A microscope of some power could be another module.

Another game "face" can identify a nearby friend and interact with them. This gets kids outside to make observations, appreciate nature, and socialize.

An example of a current science platform that might provide some inspiration is *Science Journal with Google*, which transforms an iOS or Android device or Chromebook into a pocket-size science tool that encourages students to explore their world, record observations and make discoveries. There are dozens of suggested experiments. Google provides open-source code, APIs, and Arduino firmware to encourage fresh ideas.
https://sciencejournal.withgoogle.com/

[8] MAKE LARGE SCALE ART PATTERNS OUTDOORS

Help kids learn and apply the concept of mapped routes to spatial navigation in the world around them. while moving around in the outdoors with open-ended play.

In a challenge game incorporating math and art, simple patterns are sent to the player's GPS-enabled wearable to recreate on a large scale by moving, preferably outside. Once finished, the accuracy of the player's pattern will be compared or overlayed with the challenge pattern and assigned a score.

Patterns will increase in complexity (think mandalas) for continued play. Colors could be associated with the velocity of movement.

For math integration, the challenges are sent as dimensions and angles in written form, and the figure has to be recreated in the visual pattern.

As an option for a community, players create their own pattern by walking, riding a bike, or writing, then send it to the virtual community as a challenge.

Comments from STEM Teachers – Making Art Patterns

The incorporation of open/free play, physical movement, collaboration/sharing, with art and math concepts is exactly what I want in a toy. As an add-on feature, the wearable could be attached to robots/toy cars/drones, and the challenge becomes to program the pattern to recreate it.

DESIGN AND BUILD

- Solar Building Blocks
- Weak Link
- Force-Measuring Blocks
- Enhanced Construction
- Building Challenges

The Design and Build platform explores new building block materials that incorporate STEM principles encourage solutions to real-life building challenges. Toys can include more detailed and realistic structures, and creative new ways to engage girls and boys in design and build concepts for learning and play.

[9] SOLAR BUILDING BLOCKS

With environmental concerns over our carbon-based energy use, solar power should play a much more significant role in our future, starting with our youngsters.

Kids could snap together an assortment of different shaped (recycled) plastic pieces - many with photovoltaic surfaces - to create buildings, other objects, or simply develop designs featuring pieces that "light up" after being exposed to sunlight. Some of the blocks could even be in color. While nowhere near the advances made in microprocessors, we are at the dawn of the solar age. While costs are still above fossil-fuels, higher demand for the cells will drive research to make them even more efficient.

Option - Perovskites are calcium titanate minerals that could be applied like paint to almost any substrate and turn them into photo-voltaic cells https://en.wikipedia.org/wiki/Perovskite_solar_cell.

Comments from STEM Teachers - Solar Building Blocks

- Solar cells can be added to structures for additional technology.
- Include build challenges that require "unknown" patterns or numbers of connected blocks to light up or cause a motor to turn. This would be kind of like solar *Snap Circuits*, but with an art component.

[10] WEAK LINK

Materials have limits. There is a point where a load will exceed what a component can support. The idea is a construction set with deliberate limits that have to be designed around.

Making a toy that will break under load is wasteful, so what about a construction toy with designed limits such as:

- A chain with one link out of five made of a magnetic coupler that will disengage if the load is too great.
- Gears with a mesh ring that will disengage from the shaft beyond a given torque - again, little magnets. *(Check out Polymagnets in the Appendix or at http://www.polymagnet.com/polymagnets/)*

Structural plates (long, flat and narrow) that lack rigidity (comparatively flexible plastic) but that can be assembled with others to make I-beams, "C" channels or square tubes.

The concept of fail-safe, where a system or structural component has to have enough redundancy to be tolerant of a single failure, is engineering in action. Make the most of what you have, accept the limitations of the material, and cleverly design around them.

Comments from STEM Teachers – Weak Link

- The concept that some components are built to be sacrificed to save the rest of the device is attractive. Push materials until they break and then design around the failures for success. The “weak link” concept could also be blended into other product lines in the Design and Build category.
- The failure point is an important concept to teach. The toy needs to come with some pre-made challenges to get players started.

[11] FORCE-MEASURING BLOCKS

Kids love playing with traditional building blocks, but they never know how much stress is being applied at any given point of the structure.

The set of Force-Measuring blocks would be a set of toy blocks and associated block-like forms that would be used in place of, or with, typical wooden blocks. Each translucent block would have strain gauges inside to monitor the forces applied to crush the blocks, and the amount of force measured would cause the block to glow a different color using an LED inside. A block with no force applied might glow dark blue, while adding more might cause it to glow yellow or red.

Challenging construction games could be created where if the block exceeds a particular threshold force, it turns a color indicating that the block is "broken" and that the design needs to be modified to reduce the amount of force on that block.

This is for every kid, starting with infants playing with blocks. It would require no initial skill to begin enjoying these blocks. The concept could then progress through age groups by adding more complex sensors such as a compass or magnetometer in add-on block sets.

Comments from STEM Teachers - Force-Measuring Blocks

Great idea, especially as it relates to the positive aspect of failure. Build the structure until the block indicates the structure/block is broken without breaking the toy. This concept Includes completely open play with the add-on of a physics concept. Add-on items could also include pulley systems, springs, and other components that visually indicate force.

[12] ENHANCED CONSTRUCTION

LEGO® and Lincoln Logs® let you build a house or building, and a new kind of construction toy can help kids create more realistic projects with an extra "engineering spin."

Many dollhouses require minimal assembly. It would be much more fun and educational if a dollhouse could be expanded upon as desired and have running water and electricity – even solar panels for electricity and solar collectors for hot water. The toy set could include everything from 2x4 framing pieces to walls, doors, windows, piping, wiring, and other elements. Of course, this may be expandable to include more home features and other building types.

The pieces could be fabricated such that various components may be connected in different ways, and the flexibility of the parts may allow for the construction to be as simple or as complex as desired.

It takes a toy that is relatively popular and brings it to a whole new level by allowing for customization in the construction and running "utilities" to add challenge and excitement to a toy that has previously been pretty inert.

Comments from STEM Teacher – Enhanced Construction Toys

This is a great idea, and you can add another level of interest with an online build component to make blueprints and to get building ideas or tips. Then build the design.

The product line can offer different styles and skill levels, but the same challenges.

[13] BUILDING CHALLENGES

There are many construction kits around, but how many are destined to be a challenge of competing requirements to build something with pre-set conditions and limitations?

Most building toys aim to reproduce the likeness of something. In some cases, quite detailed instructions are provided to show how to make the spaceship from a movie, or the castle from a story, and so on.

This would be a building toy with challenges and imposed limitations. *Make a bridge this long and able to support this load, but without using part XYZ. Alternatively, use a minimum of 10 parts ABC, because in real life the bridge building company had 500 of those in the inventory for another project that was canceled.*

Each challenge would be a package of unique parts and components that augment a starting set (uniquely colored for identification) with goals that would be scored (number of parts used, overall weight, and not exceeding some maximum limits.)

Builders would be scored and make the honor roll on a website, leading to the invitation to time-limited competitions.

Industry always expects to do more with less; and while something could be fully optimized and physically unable to be better, introduced constraint (time, budget, must make use of *this,* cannot use *that*) make it a whole different challenge.

It is 100% engineering, and that includes the sometimes frustrating conditions imposed by management.

DECONSTRUCT AND REDESIGN

- Composting Wired Worm Farm
- Disassembly Toolkit

The Deconstruct and Redesign platform explores the concepts of decomposition, deconstruction, and creating something quite different.

Beyond the example ideas, this is also a conceptual hub for toy companies to think about and design around— toys and activities that employ the concept of deconstruction in the natural world, and also with things large and small that are manmade.

[14] COMPOSTING WIRED WORM FARM

A composting bin that is also a worm farm combines a fundamental biological process with the ability for the user to manipulate variables to change the rate of decomposition.

Use house waste to make compost, build planters, and grow seeds. This leads to lots of experiments with soil chemistry, factors affecting the rate of growth, gravitropism, and thigmotropism.

Composting is popular and easy to do. As an added benefit, inexpensive probes can be installed to monitor several factors that can be influenced by different variables added to the container — moisture, temperature, pH, gas emissions, and more. The user can manipulate light exposure and ambient temperatures to get the best results.

The probes can connect via Bluetooth to computers or mobile devices. Users can report out to "the community" for tips, help, and challenges. This set is for all ages and will grow with the users' knowledge and acquired skills. They can scale up the sizes too. If the user has an unsuccessful experiment, they can try again. There is always something to compost. With or without worms is a choice.

Comments from STEM Teachers - Composting Wired Worm Farm

- This idea has room for growth, scale up and move outside. It allows for many possible experiments, very open ended, and the variables are unlimited. An outside community for tips and challenges would be a great addition. This could be used in school and local governments to encourage kids to compost and recycle.
- This has all the good science components - data monitoring and gathering using simple technology, supporting sustainability, and a way to submit citizen science data to the community.

[15] DISASSEMBLY TOOLKIT

The basic idea is a gizmo that is 90% complete, and here are the parts that could be used to complete it. It's up to the user to figure where they should go and why.

Maybe it's a line of "broken" toys to be fixed, but can also be fully disassembled and built to do something else. Different levels of difficulty can be with one or more components not working, including higher levels with coding/ programming. With the disassembling and reassembling, this could be a new evolution of the *Transformer* idea and could show the value of reclaimed materials in a world where we really should be doing much more of that.

At the extreme, it could be a "repurpose" challenge, just like the Apollo 13 astronauts had to improvise an adaptation of a bunch of disparate elements to make their CO_2 scrubber work with the "wrong" cartridge. It is not a "broken device." It is a gizmo that was designed to do something else, and that has to be combined with other elements in some open and smart way to achieve the goal.

Comments from STEM Teachers – Disassembly Tool Kit

Find the missing or broken part? Cool idea and a safe way to begin. We house a STEM camp for grades 1-5 and get donated equipment for the kids to take apart, identify pieces and their functions. Then they recreate all of the parts into another type of creation. What if the broken toy was able to be fixed by finding the missing or broken part, then fix it, tear it down and make something else?

DISCOVERY AND IMAGINATION

- Make a Galaxy
- Biomimetic Solutions
- CORE IDEA 2: DNA Dice
- Evolve the Dinosaur
- Creature Creator
- For the Greater Good

The Discovery and Imagination platform begins with STEM and STEAM principles in astronomy, biomimetics, genetics, and more to spark the user's creative imagination for engaging play and a different experience and outcome each time.

Real-world challenges based on contemporary goals and standards can encourage imagination of new solutions to global concerns.

[16] MAKE A GALAXY

Space is exciting and mysterious, and so much remains for us all to explore. Kids can imagine and create their own new solar systems and galaxies and see what happens!

This simulation would likely play out in VR or AR. Perhaps with further advances in technology, this toy area could be experienced in mixed reality.

The set is for individuals or a group of players to create planets, moons, and other space objects, plus their orbit paths and sizes, and properties: materials, values of gravity, atmosphere, potential life forms, and other options. They pick the stars and sun(s), perhaps a black hole and some dark matter. Then, the solar system or galaxy can be set to "go" – and watch what happens!

This lets kids explore and appreciate the makeup of our universe by building their own. It opens up the idea of building on acquired knowledge and adding *what if*?, scale, cause and effect, the potential of failing, and then trying new ideas.

[17] BIOMIMETIC SOLUTIONS

Students are always amazed at the new technology developed from a solution already existing in nature. Biomimicry is an up and coming field.

Players create solutions to "problems" with the inspiration of biomimicry — mixing characteristics of the models, systems, and elements found in nature. Challenges can be on game pieces or cards with descriptions of unique traits found in nature and problems found in our lives. Mix and match for unique creations, which can be realistic or fantastical. Solutions could be submitted and voted on by the "gaming" community. These could lead to student-designed projects to be entered in competitions.

- Sahara desert beetle with superhydrophobic shell = superhydrophobic structures to capture water vapor.
- Kingfisher beak design = noise reduction for Japanese super train.
- Helicopter seeds = seed bombing for deforestation.

This is a crossover of biology, creativity, and play.

https://biomimicry.org/ https://asknature.org/ https://biomimicry.net
https://youthchallenge.biomimicry.org/en/custom/ydcgallery/directory

Another option is to use Virtual Reality to help create and visualize entirely new “living” organisms by applying biomimetic characteristics in a virtual world to see them come to life and demonstrate their newly combined capabilities.

Comments from STEM Teachers – Biomimetic Solutions

- Approaching design and solvng problems with biomimicry, there are still plenty of disoveries to be made.
- With or without technology, it leaves the door open for players to discover an unknown use for a biological structure or process to apply to an unsolved real-life problem.

[18] CORE IDEA: DNA DICE

Players can use OLED dice (with light emitting diodes that can change color or the letters displayed) for a suite of related genetics games and roll the dice to get relevant combinations.

For the core genetics game, the dice display DNA letters A, T, G or C and a possible color representing a mutation to create life forms.

The game would provide an opportunity to be creative and learn about genetics and the building blocks of DNA. The player could see their creations on paper or avatars from a companion online source. Organisms could be made to solve challenges or compete against other living things. This utilizes current biological knowledge and imagination of the players. Even without OLED technology, this could be played with analog dice, and an expandable card set specially made for the game.

It might be interesting to see kids come up with a visual of the organism that they have rolled the dice for. The DNA "strand" might indicate (via a reference chart) a buck-toothed quadruped the size of a VW with three eyes, a stumpy tail and an ornery disposition. Doodle that and battle against your friend's organism by rolling battle dice.

There are virtual fantasy genetics games https://concord.org/teaching-genetics/dragons/, but they do not have the after play where the organisms interact.

The science education value would be to update the genetics concepts to the 21st century to include epigenetics, RNAi, mtDNA, exposome, and microbiome influence. So the dice/cards must be expandable, *or* updates include a *change* to the meaning of cards and dice or whatever the physical game pieces are *especially* as new discoveries are made.

Options: The integration of at least two OLED panels to each die, along with a tiny transceiver/microprocessor combination, would allow two things:

1. The dice could communicate with a smartphone-connected database with some AI functionality, allowing the game to adapt to the knowledge level of the players, thus offering a higher engagement/lower frustration factor.
2. The game could be, in fact, many different games, covering a wide range of subjects.

Comments from STEM Teachers - Core Idea: DNA Dice

- Combine all three great concepts *[19] Evolve the Dinosaur and [20] Creature Creator* with this core idea *[18] DNA Dice* into one game! Build an organism that has parts (physical) and characteristics (virtual platform) and have them evolve (dice) when presented with environmental changes that arise during play.
- To super-geek the game, players could research or learn to read peer-reviewed journals and incorporate discoveries into the gameplay only if the research methods are valid, or the paper is cited.

(The *Genes and Traits Learning Objective* is one of the Next Generation Science Standards presented in the NGSS Resource in the Appendix.)

[19] EVOLVE THE DINOSAUR

Life is a struggle, and conditions change. Help a dinosaur cope and thrive by giving it different body characteristics and behaviors.

The player would start with a selected dinosaur breed with preset appendages, diet, and ecological niche, with a small screen and buttons. There would be a line of starting dinosaurs, some to be herbivores, others are predators. Some to be fast and nimble, others to be strong or cunning. Some would be purely land animals; others would be amphibious or aquatic. Players could concentrate on one species or decide to manage "competing" lifeforms.

However, all those characters can be altered through mutation and selection. Does a predator too frequently target your dinosaur? You can procure the armor add-on, but at the expense of making it less mobile. Or you can get it the long legs that make it a fast runner but at the expense of increasing its nutritional need.

Once fitted with a new physical part, and using a USB-like interface so that the core of the dinosaur recognizes the new appendage and adjusts its ability and limitations accordingly, the dinosaur would then interact with a server that handles the biosphere. In turn, the biosphere would issue changing conditions for the current environment. Did a massive storm hit and flood the area? If the dinosaur is a fish eater, all is great. If the dinosaur is a large herbivore that eats grass, the player would either have to make it migrate or to start eating algae (diet change) by changing its behavior through the small interface. The challenges and responses are unlimited. The line of dinosaurs would teach about mutations, adaptation, and ecology.

Comment from STEM Teacher - Evolve a Dinosaur
A good approach, especially with the changing environmental pressures, but must be careful NOT to promote the idea that *organisms* adapt and evolve; *populations of species* evolve.

[20] CREATURE CREATOR

Take the fun and creativity of "creature games" in new directions with organism parts and unique combinations of real characteristics.

Players use an assortment of plant/animal/fantasy elements to create new organisms, which will exist physically and in the virtual world, and can interact with other players.

Each playing piece will be pre-coded with characteristics/strengths and communicate with each other to develop new characteristics.

Connect creations with an application or online software to explore their features. There can be an option to re-code pieces with new traits.

Another option can be to print 3D components and buy a chip to insert to code. Players can interact online with each other. This concept addresses the need for physical and virtual play with endless expansion opportunity.

This STEM toy set is Biology + building + programming + physical play + online play + an exponential number of possible outcomes.

Comments from STEM Teachers – Creature Creator

- All fantasy creatures have some characteristics of combinations from reality. Perhaps pieces can incorporate Merge Cube type patterns, so the physical play crosses into virtual play and adds the ability to code your own characteristics.
- There could be physical building blocks/shapes/plant/animal parts that would be assembled and interact, and there would be a dual virtual play.

[21] FOR THE GREATER GOOD

UN Sustainability Goals and research regarding Gen Z and Millennials connect interest in improving the community. Problem-solving challenges are based on current global issues.

Using the UN Sustainability Goals, design toys and kits that challenge players to come up with unique solutions to the problems.

Because the goals are so diverse, the range of toys/kits could be widely varied. From: decks of card prompts, building sets, soil/water/plant related, food and food chemistry, math-related population challenges. Problem prompts and kits easily fit into a subscription model.

A key component to this is a component of public sharing amongst the playing community — a platform where pictures/videos of their play/ideas can be shared and commented on.

This concept relates directly to the real world. It is an opportunity to create unique solutions to real problems. There should be a wide variety of toys/items that have endless iterations. It is entirely open-ended. These are problems that currently do NOT have a solution.
https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Option: Add toy kits that contain objects that can represent almost anything because they are digitally unique (i.e. a pattern similar to a QR code on the outside, embedded RFID, etc.) that allows the playing board (if that's the implementation) to recognize not only where the player's piece is, but what it represents. So, as an example, the challenge of a particular game could be to solve certain instances of drought (such as the Somalia/East Africa Famine and Drought in which reportedly killed 260,000 people). The players have a certain amount of capital, granted in equal amounts to all players in the game, and choices on how to deploy that capital.

The connected app on a mobile device, which drives the data that the playing board has access to, has several scenarios that guide gameplay and give statistics in realtime on the impact of each player's decisions. The algorithms behind the app could be structured to cover all ages (K-12 and beyond).

Comments from STEM Teachers - For the Greater Good

- It's good to have the current event style and subscription status combined. It is relevant, timely, and would have interest. The problems always change or stay the same with different parameters. It is "real-world" problem-solving. There could be contests and could generate great ideas that lead to science fairs and other scholarly endeavors.
- Allowing children/players to solve problems is powerful. The drive for Inquiry Learning and Problem-based Learning is working because it engages learners in solving problems they are interested in. The crossover to a real educational use game is evident here.

EXPLORATION AND ADVENTURE

- GIS Surveyor in the Yard
- Survival Shelter Kits
- Limnology Kits
- Sun Play at Parks

The Exploration & Adventure platform is all about engaging in real-life learning outdoors in the back yard, in parks, at the lake, or in a city.

The example concepts presented here are a mix of traditional and modern approaches to science, and all are experiences kids can build on for further exploration and adventures.

[22] GIS SURVEYOR IN THE YARD

Kids can team up with friends, apply what they're learning about geometry and trigonometry, think strategically, and have fun outdoors all at the same time.

A kit includes smart sensors to survey outdoor spaces with geometric challenges. Objects that can be placed around the yard communicate with each other, the app, and satellite data. Challenges to build 2D structures with different angles, i.e., a triangle with 50°, 20°, 20° angles, could include distances apart. If they are set up accurately, they make sound or light.

Progress to 3D structures. Trigonometry lessons could be included to calculate the height/width of a large object using sensor data. The user could place objects in various places; relative locations upload to an app to visualize the shape with distances and angles. The idea could be extended to use in the house - children could use them for mapping out their room and objects in the room. For a child, rearranging bedroom furniture is a fun activity. Think of a physical tool for simple CAD architecture.

An extension if it's made durable - add force, velocity sensors. Protective parents don't allow children out of the yard, but play needs to include some outside activity.

This STEM toy is outside/inside active play + geometry + open ended.

Comment from STEM Teacher – GIS Surveyor in the Yard
Anything that can tie math in with play is a great challenge!

[23] SURVIVAL SHELTER KITS

Kids love to play in forts, and adventurous kids would appreciate learning to apply related structural concepts and practical outdoor skills.

Create a line of small models and instructions for building simple shelter types that could help kids survive in the outdoors. They could include artificial pieces such as branches and vegetation to construct small models indoors, but then kids could then take it a step further and recreate those ideas outdoors with real materials.

Each kit could cover a different type of shelter, from a debris hut, quinzhee or lean-to, to a snow cave. The kits would cover concepts that explain why specific structures are stronger than others, in addition to tips on how to choose materials and location.

The survival shelter kit connects fun and exciting hands-on play with basic structural concepts and gives kids a real sense of confidence.

Comment from STEM Teacher – Survival Shelter Kits
Kids love to build forts and tents. It's a good approach to start small and then scale up. The ultimate goal would be to create a shelter and have a sleepout in the back yard.

[24] LIMNOLOGY KITS

Hands-on learning about the areas of science that tie into the study of inland waters such as lakes, ponds, wetlands, streams, and rivers would make for great experiences outdoors.

Kids can experiment with and learn about natural fresh water and the areas of science that are connected with it. A line of Limnology kits for kids could include fun experiments and activities that approach the different aspects of limnology: biology, chemistry, hydrology, geology, and physics.

One kit might show how to use a Secchi disk to measure water transparency and how different colors or wavelengths of light penetrate water to different depths. Another might have kids test temperatures and find the thermocline, and monitor how lakes turn over at ice up, along with how all of these things control aquatic life and where it thrives. Kids could test samples and examine various aquatic life forms.

This is a good fit for STEM because it brings many areas of science into focus and ties them to something in the real world all around us.

Comments from STEM Teachers – Limnology Kits

- This kit can also be a part of the *[6] Core Idea: STEM Sleeve* platform. The sleeve would have the information of that particular biome, and the module would include the "hardware" needed to perform experiments.
- Other areas of science that might be good for development into kits for outdoor exploration include insect pit traps, light sensors for canopy cover, and soil composition.

[25] SUN PLAY AT PARKS

When you go to the park, the sun is the main event! Park spaces allow a great chance to learn, and the tools by which to do that are much too scarce.

Parks should include activities that offer us a chance to explore more specifically what the sun does, what it means for our habitat, and what we can use its power for. These can be puzzles that explain solar power, Copernicus's studies, plants as collectors of sunlight for photosynthesis (energy and growth) and other solar concepts that can be demonstrated in ways that spark kids' curiosity.

Durable outdoor toys powered by solar cells would be very forward-thinking. Some solar panels can be angled and show changes in energy output as a function of the angle of the sun.

Comments from STEM Teachers – Sun Play at Parks

- This is a strong idea because it can be built into public parkland structures and private back yard playsets and play structures. Solar for your tree fort!
- A toy element could be a solar playground/amusement park kit.

TOYS IN CONTEXT AT NEW SPACES

- Toys in Context at New Spaces
- STEM Toys at Airports and Train Stations

The Toys in Context platform takes a cue from the time we spend, mostly waiting, staring at handheld screens in venues that could offer interesting STEM learning possibilities coordinated with real-life experiences.

This is an untapped opportunity for toy companies and potential partners to leverage these experiences in creative and meaningful ways, and to take toy retail into completely new places.

[26] TOYS IN CONTEXT AT NEW SPACES

The embedded wait time families experience at many venues presents opportunities for alternatives to "screen time," and new outlets for STEM toys with add-ons and expansion kits.

Engine basics at the car repair shop: A physical replica or simulation car engine game would be a stimulating activity for kids waiting with parents for the car repair. Most play areas in these spaces are pretty basic and miss opportunities for children to explore automotive engineering.

A building toy or game could be created with moveable parts to demonstrate how auto engines work, and there could be corresponding storyboards showing each step of the construction. Children would be encouraged to tinker and experience the cause and effect of their actions.

A line of toys expanding on this concept could be developed and featured at different dealerships or service centers and sold in stores. Car dealerships already offer a video of your car getting its diagnostic tests in real time, and this could be incorporated into the game to make it personal.

Automotive engineering requires many STEM skills, from design to interpreting data and analyzing problems. All children ride in cars, but how many understand how the engine works? Having an engine to take apart and rebuild gives them an engaging and fascinating activity. The idea opens up a new area for technical automotive toys, introducing all kids to mechanics and relating science to everyday life. Critical thinking and creative problem-solving skills are necessary to complete the challenges.

Thinking about nationwide chain businesses – in-store experiences and take-home toys:

- Using and building cosmetic tools, add-ons include chemistry of cosmetics.
- Restaurant toys replicate parts of the menu. Extensions could include chemistry of food, molecular phase change with heat, acid-base, lipid interactions. Send out a monthly kid-friendly recipe to apply the principles.

- Hotel chain: toys to model a hotel/building, water chemistry for pools and saunas, build and experiment with elevators/pulleys, more complex problems like system engineering for placing/servicing customers (teaching computational thinking).
- Electronics stores: Building and problem solving with any electronic, appliance, computer, and coding. All models could have a subscription that sends a new component or challenge, with a coupon from the business. All models could have a virtual sharing component or competition. Versions can include surprise packaging and limited production kits to encourage a secondary trade market. All versions could have a walk-in-only toy to entice patrons.

Also assuming that the toy would be double branded: toy manufacturer and business chain:

- McDonald's Happy Meal toys, for example: gender neutral and partners with established brands. Hands-on critical thinking play for use at a time when the child may be waiting.
- Retail pharmacy stores integrate health, medicine, pharmacy, and chemistry learning toys.

Comment from STEM Teacher – Toys in Context at New Venues
All are creative uses of wait time. That time is competing for screen time - so tie the physical play in with the virtual aspect. Share a picture of the toy/creation that is hosted by the company/store, including QR codes on the toys to give secret hints.

[27] STEM TOYS AT AIRPORTS AND TRAIN STATIONS

There is a lot of downtime waiting for planes, and an exploration area at the airport could be an excellent introduction to the toys that explore the aspects and experiences of flight.

How does that plane stay in the air? Create a line of toys for all ages - model kits, simple experiments, and games that demonstrate the principles of flight in fun and creative ways. A kiosk center or vending machine at the airport could sell the STEM toys connected with experiences kids have at the airport and on a plane. Kits can also include modules for learning more about the different clouds and landforms observed out the window of the aircraft.

There are lots of examples of this type of play at science museums, and it would be great to put it at the airport. Ideas could include a hand crank lift to launch a paper airplane, a hand-controlled plane in a variable wind tunnel, and hands-on models of propeller crank vs. jet engines. Just listening to the tower and pilots communicating would be an interesting informative element.

A STEM learning approach adapted for train travel, which is usually a more extended experience, would also be interesting and relevant. Most major train stations have shops, kiosks and high end vending machines.

Comment from STEM Teacher – STEM Toys at Airports & Stations
There are teachable moments everywhere and in most situations. STEM toys should make users aware of why things work while they have an enjoyable time. Playing is learning, and learning is life.

STEM PLAY WITH PETS

- STEM-based Kits for DIY Pet Toys
- STEM-based Kits for Agility Training

Pet care continues to be a growing industry, and sales of pet toys such as fetch toys, rope/pull toys, interactive/training toys, and treat-dispensing toys top $1B. *(More information about the pet toy market at this link.)*

New lines of STEM-related pet toys can help kids develop new skills, connect with their pets in fun and creative ways, and also introduce opportunities to take toys into new retail channels.

[28] STEM PLAY WITH PETS

The games you play with your dog have some strong math and science concepts behind them, such as force in a tug-of-war, and angle of throw, pursuit, speed of retrieval in fetch.

STEM-Based Kits for Designing and Building Engaging Pet Toys

Use the toys you create to enhance play with the family pets. Build a catapult, slingshot, trebuchet, air cannon to launch balls for the dog to fetch. Design and build a laser or RC car/mouse/ squirrel for your dog or cat to chase. Create something completely new. Twice the fun, make it and play!

STEM-Based Kits for Agility Training

Agility training is another opportunity for incorporation of STEM in play for families and their pets. Designing and building the course and challenges, dealing with space constraints and different size dogs, all include problem-solving aspects. The components of STEM, including force, velocity, area, and coding, are used to solve problems.

Comment from STEM Teacher – STEM Play with Pets

There would need to be some sensor to track the values associated with these motions, but it could provide a way to weave STEM concepts into engaging play with pets.

APPENDIX

RESOURCES:

Next Generation Science Standards (NGSS)

STEM/STEAM Wearables & Smart Textiles
(Design Partners, Thought Leaders, and Relevant Research)

ADDITIONAL STEM AND STEAM TOY IDEAS:

29. World of Wheels
30. Color and Light
31. LED Lighting Design, Build and Embed
32. Environment Playboards
33. AR Chemistry Adventure
34. Phenomenal Phenomena
35. Shock Absorption Fun
36. Physics and Biology Crossover
37. Connect Sport and Science
38. STEAM with Fiber
39. Traffic Master
40. Space and Time

RESOURCES: NEXT GENERATION SCIENCE STANDARDS

Several of the comments from our STEM teachers refer to NGSS – Next Generation Science Standards for grades K-12. Here are recommended resources to learn more about NGSS and Three-Dimensional Learning (Practices, Crosscutting Concepts, and Disciplinary Core Ideas), which may inform and inspire the creation and development of STEM toys.

NGSS Website
https://www.nextgenscience.org/

NGSS Three-Dimensional Learning
https://www.nextgenscience.org/three-dimensions

Topic Arrangements of the NGSS
https://www.nextgenscience.org/search-standards

Crosscutting Concepts – Linking domains of science
https://ngss.nsta.org/CrosscuttingConceptsFull.aspx

The Wonder of Science – Resources from teachers implementing NGSS
https://thewonderofscience.com/

Phenomena – Natural events that occur in the universe
https://www.georgiascienceteacher.org/phenomena/using-in-GSE/

NGSS STORYlines - Incorporating fiction & pop culture in science classrooms
https://www.rubicon.com/ngss-storylines/

RESOURCES: STEM/STEAM WEARABLES & SMART TEXTILES

Design Partners • Thought Leaders • Relevant Research

Smart Textiles for Designers: Inventing the Future of Fabrics

by Rebeccah Pailes-Freidman
https://www.getinterwoven.com/our-work/smart-textiles-designers/

Advanced Textiles Source from Industrial Fabrics Association International

https://advancedtextilessource.com/back-issues/

Material Conexion is a leading materials-driven design resource

https://www.materialconnexion.com/innovation-wall-topics/

Soft Circuits

https://loomia.com/blog/2019/4/5/an-intro-to-e-textiles-soft-circuits

Polymagnets—smart magnets for product design that surprises the senses - entirely new types of magnetic systems

http://www.polymagnet.com/polymagnets/
http://www.polymagnet.com/media/WP-PolyMagnets-Advanced.pdf

Wearables will go beyond attached and embedded sensors

https://gadgetsandwearables.com/2018/12/20/best-smart-clothing/

Any wearable or toy that incorporates motion could have kinetic charging

https://greendiary.com/works-kinetic-phone-charger.html

Smart Clothes and Wearables—UX Design Perspective

https://link.springer.com/chapter/10.1007/978-3-319-50124-6_12
Häkkilä J. (2017) In Schneegass S., Amft O. (eds) Smart Textiles

Designing (Inter)Active Costumes for Professional Stages

https://link.springer.com/chapter/10.1007/978-3-319-50124-6_13
Honauer M. (2017) In Schneegass S., Amft O. (eds) Smart Textiles

[30] COLOR AND LIGHT

Thermochromatic pigments housed in plastic chips used as "pixels," form an image that will be affected by temperature change when touched or allowed to cool. A canvas composed of a matrix of cells, each housing one or several translucent plastic chips that contain thermochromic pigments that change between specific colors at a given temperature. The pieces could be moveable or interchangeable, and players could swap out different temperature range chips. The resulting artform is one that will change color and aspect as a function of the temperature when touched by hand, or allowed to cool. Adding prisms and optic conduits (optic fibers) would add even more capabilities.

It would teach that an object is created from parts that may appear or act differently depending on conditions in reaction to the environment. The translucence of the chips will teach about additive and subtractive color. Painting with color and light, particularly if those are changing, could trigger interest in learning more about the property of light, and how it behaves.

Comment from STEM Teacher – Color and Light

Creating some design challenges would add to the learning aspect. Players would have to manipulate temperature and location in order to recreate patterns. A design sharing portal would build a community and allow players to show off creations and challenge one another. Players could display how their toy looks outside during different times of the year and relate that to climate patterns.

[29] WORLD OF WHEELS

Cars and trucks have always been popular. This toy allows kids to experiment with how propelling them can change when wheel dynamics are altered. A block or other shape would come with a vast amount of different sizes and shapes of wheels, even oblong and square, thick and thin.

Youngsters could experiment with different combinations, fast, wobbly, bigger in front, or larger in back. Children know that wheels help objects move, but may not understand why specific sizes or shapes are better. This is an area of knowledge that's taken for granted – how and why wheels work. It would be a fun way to learn something fairly basic.

Comment from STEM Teacher – World of Wheels

This is a good concept for younger children. It has many variables to manipulate and can be expanded with age or skill by introducing math (ratios, angles), adding or subtracting weights or forces (friction).

[35] SHOCK ABSORPTION FUN

Much engineering goes into minimizing the effects of an impact. Helmet technology is probably the one most familiar to kids even if they don't stop to think much about it. What if there were a line of toys that could get them thinking about it? Many materials, such as foam, gels, liquids, and air, are employed to absorb all kinds of impacts. Toys could help kids experiment with different techniques and samples of these materials to prevent damage to the toy. Breaking the toy would not be "fun," so it should be tough to do. However, a toy could show virtual damage to give the child feedback about the protection a material might provide for a particular activity.

Comments from STEM Teachers - Shock Absorption Fun

- The egg drop challenge is a common physics/engineering lesson used in school, and students love it. I like the idea of making an egg-shaped force sensor.This can lead to fully open-ended play, and an endless number of household items can be tested for impact absorption. You could learn about the impact force of everyday actions: put it in the dryer to measure the forces there, play catch with it, hit it with a tennis racket.
- Make a game out of it, who can drop the “EGG” from the highest place or throw it highest without damage. Provide some materials and encourage the kids to adapt new items to use. Make the “EGG” attachable to stomp rockets, catapults, and slingshots. This can be for indoors or outdoors.
- G-force tech is out there. It's in baseballs to measure velocity, but the sensor gets destroyed; we found out the hard way. I like the idea of building sensors into toys. They could find their way into helmets for sports (skateboarding, skiing, snowboarding) to show parents if their kids took a nasty spill and possibly concussed. *Impulse Theorem* is all about extending the time of the collision to reduce the acceleration (Impact) - a valuable lesson to be learned. Also, parents would want to know if an accident occurred or a high force was imparted to their child.

[32] ENVIRONMENT PLAYBOARDS

A new toy category, the stacked "PlayBoard" uses embedded intelligence. It integrates a physical 3D game board structure comprised of stackable, flat plastic levels/surfaces, with "purchasable" collections of playing pieces - magnetized, embedded RFIDs sold in groups representing categories of information and gameplay — ranging from the conceptual (mathematics, physics) to the physical (astronomical to geological to macro to micro).

Each level of the stacked board represents a layer of that macro environment – i.e., the top board may be the atmosphere, next level down represents the surface of the land/oceans, next level down represents the tectonic plates, next level down represents the mantle).

An example - Under the Sea: The various collections of physical playing pieces represent, for example, ocean current flows, aquatic life, and large formations. The player uses their tablet (or a large smartphone) to show the effects of the interaction of the gameplay. The game connects with an app on the smartphone which is connected to a cloud-based database of information representing both physical world relationships (i.e., climate science, geological formations including tectonic forces) and the impact of moving pieces in three dimensions on the boards, creating interactions within their environments such as the oceans.

Comment from STEM Teacher - Environment Playboards

This is good integration of earth systems and the opportunity to teach cause and effect and systems. There is an opportunity to include mathematical relationships between temp/mass/height/material and change in the system. The game includes the chance to make predictions about a model prior to building or model disruption. Challenges to decrease the temperature of model layers, increase oxygen output in layers. The expansion could include fantasy pieces.

[33] AR CHEMISTRY ADVENTURE

Using a physical Periodic Table and smartphone, kids gather elements to create items they need in their game. They will learn chemistry principles to create the items, and more valuable items will require greater knowledge of the elements.

There are two components: a physical periodic table and an accompanying smartphone app. The goal of the game is gathering items to unlock all the elements on the board. For example, you start with Hydrogen and Oxygen and need to make water to get the key to unlocking Helium, and so on. The elements could be personified to create more appeal to different ages. (The *2017 Microsoft Hololens Developer of the Year* showcased a similar novelty of visualizing the periodic table in VR.)

This idea builds on that by using a physical product in conjunction with Augmented Reality. This is adaptive and as kids progress, their knowledge grows along with the difficulty of the game. Augmented Reality is accessible and currently being used in some lines of toys.

Comment from STEM Teacher – AR Chemistry Adventure

It's good to know the elements, but the beauty of the Periodic Table is how it works and makes Chemistry work. Knowledge of the patterns and properties leads one in how to navigate it, how elements pair up and in what combinations. As a science teacher, I think that any exposure is good exposure. I don't think most younger kids realize that things are made up of other things (compounds and molecules).

[37] CONNECT SPORT AND SCIENCE

Connect sport and science. Build hand-eye coordination with Bernoulli's principle by floating a ball and trying to hit it with a bat or racquet. Use a build-it-yourself kit that you can play with later.

The line of kits incorporates science, engineering, and games to mix the jock and geek interests. Other sports options could include Lacrosse and lever. Projectile motion is a part of most sports as is friction or lack thereof. The Olympics are always a great way to introduce physics and sports in the classroom.

Comments from STEM Teachers – Connect Sport and Science

There is room to grow with this concept. Sports can be racing bikes, cars, boats, and building better race craft.

[34] PHENOMENAL PHENOMENA

A series of Explorer Kits - toys/experiments that deal with natural phenomena – natural events that occur in the universe - like density, buoyancy, condensation, gravity, rainbows, clouds, dew. Phenomena are at the core of the Next Generation Science Standards (NGSS).

The idea is to create several toys and experiments for K-12 kids that are based upon natural phenomena that they are used to observing, but never ask why or how it happens. Kids know a lot of science, it's just that they don't know what they know. This product line can teach what is already known and just not obvious yet. Examples of phenomena are gravity, morning dew, why a Mylar balloon is on the ground in the morning and pulling the string straight up in the afternoon (gas laws), friction, the list goes on and on. Some are easy and no to low tech, others could include electronic probes.

(See a useful resource about Phenomena on the NGSS page in the Appendix of this document.)

[31] LED LIGHTING DESIGN, BUILD AND EMBED

Provide the basics for electrical circuits to design LED lighting to put into anything. The ways to incorporate the LEDs are endless and limited by one's creativity. Provide LED lights, switches, resistors. Users can design what they want the LEDs to do - blink, change color, indicate and embellish/customize things they already have like their car, a hat, calculator, skis, drone, rockets.

LEDs are common, but the STEM part of design and building are hidden. This set can foster creativity and science. The only things I have seen are DIY plans online. LEDs are everywhere and are cool, but what kid knows how to design and build what they want? This kit combines circuits, electricity, and creativity.

Comments from STEM Teachers – LED Lighting Design

This is a good open concept build and design that is applicable to many of the build/design toy ideas and platforms. Cheap, easy to work with, low voltage battery operated and twinkly. Can be an add-on to many items.

[36] PHYSICS AND BIOLOGY CROSSOVER

Start with a set of geometric shapes for engineering or biological-style pieces. Build muscles, attaching them to levers (or bones), pushing and pulling to see forces. Build structures and visualize forces acting on each section of the structure with building pieces that display the mass and direction of forces when assembled. Maybe color change is associated with the increase of force, or perhaps a temperature sensor.

Demonstrate the strength of biological structures. Look for failure points related to mass and angles.

Have an online platform to share structures, leaderboards of greatest mass with least force, most significant force without coming apart.

This STEM toy connection between biology and physics is hands-on + physics + open-ended + virtual sharing + fail & rebuild.

Comment from STEM Teacher – Physics and Biology Crossover

Making the connection between the sciences is high level learning and is something to strive for. This idea might also make an excellent addition as an add-on to another line of build and design toys.

Demonstrating ANY connection between scientific strands is a powerful tool as emphasized in **NGSS Crosscutting Concepts:** patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change.

(See a useful resource about Crosscutting Concepts on the NGSS page in the Appendix of this document.)

[38] STEAM WITH FABRIC

Most design and construction toys for STEM are blocks or objects made with 3D printers. More STEAM-focused creative design and making experiences can focus on fiber and textiles—quilts, block printing, weaving, clothes for dolls, soft sculpture, creative challenges like *Project Runway*, and other accessible learning activities.

These kits, with tools and supplies, could be offered on a subscription basis with related online video content to inform and inspire.

While not a typical STEM/STEAM product line, making with fabric involves essential skills such as problem-solving, learning how to operate small machinery, putting elements together, and a sense of accomplishment— all of which are important in the STEM field. Other aspects include exploring the properties of different fibers and textiles, color theory, and math. Quilt piecing, pattern drafting, and weaving use fairly complex thought processes, and yet they're not seen by the larger society as a complex, technical feat of construction.

Connection with STEM skills for both girls and boys is clear. In an age when kids spend so much time in repetitive tapping and swiping mobile device screens, these "made by hand" STEAM activities help refine manual dexterity and small motor skills that will likely be useful in many future STEM activities and careers.

A chemical engineer and inventor on the Prodigies team noted, *"When I would interview engineering graduates for jobs, women often did not have good examples of putting engineering concepts to practice. One chemical engineering candidate used a story about sewing her own clothes and nailed it. In the evaluation meeting at the end, one of the male directors commented that she had the best example of real-life use of engineering concepts he had ever heard from a candidate."*

[39] TRAFFIC MASTER

Juggling many balls, untangling gnarled messes, and most of all, maintaining calm focus are specialized STEM-related skills that apply to thousands of jobs and tasks. Automation inevitably breaks at the most inopportune times or could get compromised in a cyber attack. The heroes that save the day might be the ones that have trained for this moment since they were young, even if they didn't realize it. A line of toys and games for one or more players could help kids explore and develop these skills.

There is also another kind of traffic control - a dispatcher job performed by someone who still has to have a handle on a broader picture, such as a fleet of vehicles making deliveries to multiple locations over the course of the day. Being mindful of efficiencies such as time, distance, fuel usage, specific customer preferences, is crucial. Intimate knowledge of the playing field (i.e., the map) is important.

Software has been developed over the years to take a lot of these decisions out of the hands of humans who are not universally good at them. The move to self-driving cars is one example. These are inevitable, but does this risk under-development of these skills?

Comments from STEM Teachers – Traffic Master

- I'm thinking about the air traffic controller, emergency management, military command scenarios. Making decisions, prioritizing, developing strategies, and coping with an evolving and dynamic situation make games fun and challenging. Computer-oriented games would give the appropriate pace better than board games.
- This could be a type of conveyor belt, assembly line game.
- Collaborating to solve problems is an essential element of STEM. When my science students do group projects/problem solving, they self and peer evaluate work contribution. If students do not contribute enough, it costs them points, and if they over-contribute (do all the work), they also lose points because it destroys trust within the team.

[40] SPACE AND TIME

Many jobs entail filling spaces (a room, a container, a truck, shipping pallets) with objects. To do it both efficiently and quickly is not an easy challenge for most. This idea challenges kids to think not only in three dimensions but also to predict efficiencies gained or lost in the process of loading and unloading.

A line of STEM toys can challenge kids to think in 3D to maximize the space they are working with. The toys and games also challenge the user to think about how the unloading or unpacking would happen. Would the way it was loaded slow things down during the unloading? How can space be maximized? Is time lost on one end, but gained on the other for a net gain? Is weight distribution a factor?

Space and Time exploration could be a board game, a 3D puzzle, a platform that tips if it's not loaded correctly, or a Virtual Reality game.

Comments from STEM Teachers – Space and Time

- This might also be a good concept to go with *[26] Embedded Wait Time* toys. As a family, we visited Scott's Bluff museum on the Oregon Trail, and in the museum, they had a "pack the wagon" interactive display. My kids had a great time trying to figure out how to pack all of the supplies in the wagon to make them fit for the "Oregon Trail trip." They also had to make decisions and prioritize what was needed and what to discard. Another setting for this STEM line could be at an airport, working out how to order planes on the runway or load luggage efficiently.
- Like a physical game of *Tetris*, it can also be added to the earlier idea *[11] Force-Measuring Blocks* that have LEDs to indicate when there is too much force on a block.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