Invention through Form and Function Analogy

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Comments from Contributing Reviewers:

“[Third grade students] loved working together and the challenge of the card sets. I loved how they suddenly realized that so many inventions were extensions of the human body. One of my students said, “I can't believe I never realized how amazing my hands are!”

“Invention units such as this one force students to consider the fact that early, seemingly simple and rudimentary inventions, led the way for the more advanced inventions that we use today. My students are now thinking about the limitations of inventions that we currently use.”

“My students and I have greatly enjoyed these lessons, I chose to do multiple levels [5th grade, 7th grade, and 8th grade] to experiment with how it would work, so far it is great in all three levels and I am planning on trying it with even younger students. I love this unit and will use it frequently!”

“Fifth grade students realized that it is because of our basic human needs plus our own human creativity and ingenuity that leads to every single invention in today’s world. We even listed things like folklore, mythology, and religion as an invention to meet the basic human needs of acceptance, community, and a need for understanding of self and the world.”

“The [fourth grade] students seemed to most enjoy putting the lesson 6 cards into order. “It is like a puzzle!” The storage of music cards were favorites because the students were very familiar with iPod, CD, sheet music, and even the magnetic tape. They seemed to gain the most learning from seeing the precursors of the inventions they were familiar with, and how the limitations of each stage were solved by a later stage of the invention. It was neat to ask them to consider what made it easier to determine order and what made it more difficult (metacognition). They very much enjoyed the hands-on nature of the cards and sharing their thoughts during discussions.”

“Overall, it made me eager to do similar activities with other students. I think the book of suggested lessons takes a lot of the “How?” out of deciding to teach invention to elementary students by providing a strong set of activities that teachers can easily incorporate and link to other studies.”

I truly enjoyed giving [students] this challenge. Once the first set was done, they were a little disappointed to know that we were spacing it out over a few days so we could talk about why the selections were made. They were very excited for the next day!!
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Introduction

The skills addressed by the exercises in this book are important. Talent, thinking skills, and innovation/inventiveness are necessary for a successful society with a high standard of living, especially in a rapidly changing global economy. “Commercially viable innovations are becoming the linchpin of success in global markets by helping to raise total productivity, and they account for a major portion of the growth in advanced and industrializing economies,” (Yusuf, 2009, p. 1). Research has long ago shown that creativity and innovation skills can be taught (Torrance, 1963), but many schools are not addressing them, partly because of a lack of appropriate curriculum (Wagner, 2010). Advances in school curriculum are necessary to fill the demand for well-prepared workers with developed problem-solving skills. This book presents a curriculum for teaching about creativity and invention from the scientific form and function approach, combined with analogy and other creative skills.

Many 21st Century skill sets, designed for the new era of quickly-evolving technologies, jobs, and culture, focus on creativity, invention, and innovation. For example, the Partnership for 21st Century Skills (2011) published a Framework for 21st Century Learning that includes learning and innovation skills of critical thinking, communication, collaboration, and creativity. The Association for Supervision and Curriculum Development’s position statement (2008) asks for teaching, learning, and leadership that adequately prepare students who can demonstrate creativity, innovation, and flexibility. The Next Generation Science Standards, based on the National Research Council’s (2012) A Framework for K-12 Science Education include standards for engineering and invention. For instance, at the fourth grade level, students are asked to “Apply scientific ideas to design, test, and refine a device that converts energy from one form to another” (Standard 4-PS3-4; Achieve, Inc., 2013, p. 31). A handbook of curriculum for teaching about invention that includes hands-on materials and creative approaches will fill a need for many teachers, as well as leaders of scouting and youth organizations. The following section provides a literature review of teaching invention through analogy with a form and function approach.

Analogical Thinking in Science Learning and Invention

Fundamental cognitive operations for learning include determining similarities and differences between objects or events. Four key strategies for assisting students in using these fundamental operations (Marzano, Pickering, & Pollock, 2001) are (1) comparing similar characteristics and differences between the objects or events; (2) classifying items into categories based on attributes; (3) creating analogies that map relationships between pairs of concepts; and (4) creating metaphors that show similar patterns from different domains. A meta-analysis (Apthorp, Dean & Igel, 2012) of published studies that centered on using similarities and
differences, such as analogy with kindergarten through high school students, found that these approaches positively affected student learning.

**Metaphors**

Metaphors, figures of speech in which a word or phrase is applied to something in a non-literal way to suggest a comparison or resemblance, can assist students in understanding new experiences by connecting them to previous knowledge. Elementary students often spontaneously suggest metaphors as they engage in science observations of nature. Jakobson and Wickman (2007) noted that these comparisons of the observed natural phenomena to qualities of other things assisted students in maintaining attention and in remembering characteristics. These researchers also observed that students’ spontaneous comparisons were springboards to constructing the final science concepts, rather than being endpoints in themselves.

At times, students’ use of metaphors can restrict what they observe, preventing other important observations from being made. Teachers’ interactions with the students through asking questions can assist students in noticing important phenomena and characteristics. Students may make comparisons to objects without indicating how they are specifically connected through shared qualities; again, teachers can assist by asking students which qualities make these objects similar to the natural phenomena they are exploring. Because understandings of metaphors are based on prior experiences, all comparisons will not be equally effective for all students. Sometimes students’ metaphors contain negative aesthetic or value judgments that prevent students from exploring the phenomena further. Jakobson and Wickman (2007) suggested that teachers might make a game of students generating positive metaphors when the conversation is negative. Finally, a teacher might mediate metaphors that appeal mostly to one gender or culture by suggesting additional, more universal comparisons. The emotional or value judgment aspect of metaphors makes them useful in creative writing and poetry. Such creative writing activities may be motivating to students in studying science, as has been shown by Rule, Carnicelli, and Kane (2004), who used poetry-writing about minerals to motivate high school students in an earth science class.

**Analogies**

Analogies make a direct comparison between objects, concepts, or events to draw attention to the common relationships of their various features, avoiding emotional reactions and value judgments. Analogies assist student learning in many ways (Venville & Treagust, 1996): (1) transferring the structure from an unfamiliar domain to a familiar one, thereby aiding comprehension; (2) motivating students through recognition of familiar aspects and increasing their science self-efficacy; (3) easing a change in mindset of the learner from “matter” to
“processes”; and (4) supporting memory through recall of features and relationships of a concept. Further substantiation of the usefulness of analogical thinking in memory retrieval comes from research conducted by Gentner, Loewenstein, Thompson, and Forbus (2009). They found that, when analogical comparisons were used during learning, later retrieval of information was improved. They attributed this to student mental representation of the information in abstract comparison categories.

Analogies provide early mental models that connect prior knowledge to developing understandings. Unfortunately, analogical thinking can be misused and lead to misconceptions when a learner interprets unshared attributes as valid or when learners are not familiar with the analogy (Harrison & Treagust, 1993). To prevent these problems, teachers need to guide students in mapping the relevant features of the analogy and in identifying its limits (Adúriz-Bravo, Bonan, Galli, Chion, & Meinardi, 2005).

A teaching model that assists students in avoiding some of the problems associated with using analogies with complex concepts is the Teaching with Analogies Model (Glynn, 2007, 2004; Glynn, Duit, & Thiele, 1995). This model has six steps: (1) introduce the target concept, a new, unfamiliar idea; (2) present the familiar concept to which the target concept is compared and remind students of its features (called the analog); (3) recognize the most important features of both the target and analog concepts; (4) connect the identified ideas from the target and analog that have the same types of relationships by making a diagram or chart (called mapping); (5) identify areas in which the comparison breaks down (called the limits of the analogy); and (6) draw conclusions about the target concept, identifying new student understandings made through the analogy. For this teaching model to work well, both target and analog need to have several similar features; the more features shared by target and analog, the better the analogy. Structural alignment is the pairing of parts from the target and analog that have similar roles in each system. This task is accomplished through mapping on a diagram or chart that connects the paired features. The paired elements do not have to have similar visual or surface appearances; the important aspect of pairing is similar relationships to other components in their systems. The Teaching with Analogies Model will be used in the proposed project to ensure effective use of analogies.

Form and Function Analogies

Analogies can assist students in going beyond memorization of features to conceptualize relationships between structure and function within a complex system. Creating analogies exercises students’ higher levels of thinking, actively engaging them in the process of making sense of a system (Marzano, et al., 2001). For example, middle school learners who created models of cells as baseball games, cities, restaurants, or homes (Grady & Jeanpierre, 2011) evidenced higher test scores compared to control groups, showing students’ improved
comprehension of cell parts and functions. Nevertheless, the isolated use of analogies is not enough to develop deep understanding; students need opportunities to verbalize their understandings, to discuss ideas, and apply the new learning (Guerra-Ramos, 2011).

**Form and function** is a unifying concept of science identified in the National Science Education Standards (National Committee on Science Education Standards and Assessment and National Research Council, 1996). This concept is applicable to both the natural and designed world, thereby supporting analogies between these domains. **Form** is any physical attribute of an object such as shape, color, configuration, pattern of motion, texture, sound, smell, taste, and so forth. **Function** refers to the use, purpose, or task of a component. Forms support the functions of manufactured objects, animal body parts, plant parts, and other aspects of organisms. For example, the sharp, narrow (form) spines on a cactus conserve evaporation of water and prevent many browsers from eating the plant (functions). Several research studies have been conducted regarding the use of form and function analogies in science instruction. Rule and Furleretti (2004) found that high school students who used form and function analogies to learn human body systems had greater gains with a large effect size than a control group. Similarly, Rule, Baldwin, and Schell (2008) showed that second graders learned animal adaptations better using form and function analogies compared to reading informational text about animal adaptations and researching the information via the Internet. These two studies utilized a unique instructional material called an “object box,” which is described next.

An effective science teaching material that uses form and function analogies is called a form and function analogy object box. This teaching material consists of a set of small, familiar, manufactured items (the “objects”), each representing an analog, and a set of corresponding two-sided cards housed in a plastic shoebox (the “box”). The front of each card describes the form and function of an animal body part (second grade study on animal adaptations by Rule, Baldwin, & Schell, 2008) or a component of a human body system (high school study by Rule & Furleretti, 2004). To begin, the student takes a card, reads about the form and function, and then searches through the given manufactured items to locate one with a similar form and function. Advantages of this object box activity include being hands-on and having concrete examples of the analogs for students to examine. The reverse side of each card provides the name of the correct analogous object and explains how its form and function corresponds to that of the target.

**Form and Function Analogies in Problem-Solving and Innovation**

Innovation is the process of creating new products or services, or enhancements to existing products or services. Organizational processes that significantly impact a person, group, organization, industry, or society are also types of innovations (Higgins, 1996). Analogies can be valuable in solving problems and developing innovations. A solver who recognizes the similarities
between two analogous problems and who can also recall the solution to the analog problem is likely to be able to apply this information to solving the new problem (Condell, Wade, Galway, McBride, Gormley, Brennan, & Somasundram, 2010). Practice in comparing two similar problems helps people develop a general schema that operates across domains. This skill allows problem solvers to be more able to consider the problem in broad terms and use analogous thinking to solve it.

The use of analogy assists scientists in making structured connections between different domains to better understand how they work and to exploit well-known relationships in one domain for innovations in another. Many scientists and inventors have used analogy to assist them in making conceptual breakthroughs. James Dyson, while looking for ways to make vacuum cleaners more effective, observed the whirling action of a sawmill cyclone sucking sawdust without becoming clogged. His first vacuum cleaner prototype was based on this analogy (Foreman & Drummond, 2008). Hans Krebs defined the citric acid cycle, later named the Krebs Cycle, by recognizing the similarities of parts of the chain to components in other cyclic processes (Lightman, 2005). Charles Darwin compared evolution to a tree, connecting budding twigs to existing species and older growth as the long succession of extinct organisms. He noticed that new growth overtops older branches, blocking the light from them in the same way that new species outcompete others in the struggle for resources. This analogy helped Darwin notice other aspects of evolution to investigate (Darwin, 1859; Marcelos & Nagem, 2012).

Form and function analogies have been combined successfully with the SCAMPER method to create new inventions or innovations of manufactured items (Rule, Baldwin, & Schell, 2009). This creative thinking technique’s name, SCAMPER (Eberle, 1972), is an acronym for various operations that can produce changes for innovations: Substitute, Combine, Adapt, Modify-Minify-Maximize, Put-to-another-use, Eliminate, and Rearrange. These ideas were developed from Osborn’s checklist (1963) of tactics for producing creative transformations. First, an item is identified to which innovation or invention will be applied. In work with second graders, Rule et al. (2009) used simple items such as an envelope, plastic spoon, or paper cup. A chart is used to implement this technique. The first column has the creative SCAMPER operations that will be applied to ideas; the second column is used to note a form and function relationship present in one or more organisms that will be applied to the item in conjunction with the SCAMPER operation to generate ideas for innovation. The combination of disparate ideas in this manner is called forced relationships, an effective strategy for producing novel ideas (Guilford, 1986). The last column shows ideas for innovation of the product.
Human Need and Invention

Maslow’s hierarchy of needs shows the stages of human need starting with the foundational base of the pyramid that shows physiological needs (Hagerty, 1999). Needs farther up the pyramid become more complex and include safety needs, social needs, esteem needs, and, at the top, self-actualization. Humans everywhere create inventions to better satisfy their needs. These inventions include tools and social constructions such as family structures, religion, community organization, and government. Table 1 shows the five sets of needs, example specific requirements, and inventions that have addressed that need area. Humans have satisfied their needs throughout history by making more sophisticated inventions.

Table 1. Maslow’s Hierarchy of Needs and How these Connect with Inventions

<table>
<thead>
<tr>
<th>General Category of Need</th>
<th>Example Specific Needs</th>
<th>Examples of Inventions that Support that Area of Need</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Actualization</td>
<td>Achieving one’s full potential</td>
<td>Research technology such as specialized equipment and computers, books on creativity</td>
</tr>
<tr>
<td>Esteem</td>
<td>Prestige and feeling of accomplishment</td>
<td>Awards, stickers, trophies; Facebook pages, plastic surgery</td>
</tr>
<tr>
<td>Belongingness and love</td>
<td>Intimate relationships, family, friends</td>
<td>Writing for communication; cell phone, photographs, scrapbooks</td>
</tr>
<tr>
<td>Safety</td>
<td>Security and safety</td>
<td>Pocket pepper spray, weapons, alarm systems, fences, locks, antibiotics</td>
</tr>
<tr>
<td>Physiological needs</td>
<td>Air, water, food, warmth, shelter, rest</td>
<td>Scuba equipment, gourmet food, food processor, microwave oven, bunk beds</td>
</tr>
</tbody>
</table>

Cultural Universals

Cultural universals are basic categories of human social experience that have existed in all cultures, past and present. These cultural universals include activities and inventions related to basic human needs of food, clothing, shelter, family structures, communication, government, transportation, religion, occupations, and recreation. Although these cultural universals can be found in all societies, they do not necessarily take the same form. They are heavily influenced by local climate, geographical features, natural resources, and available materials (Brophy & Alleman, 2006).
Lesson 1

Identifying Forms and Functions of Objects

Objective: Students will be able to tell what is meant by the terms “form” and “function” and will be able to identify forms and functions of given objects.

Exploration: Ask students to write a definition for “form” and for “function” followed by examples of each. Discuss their ideas.

Explanation: One of the unifying concepts and processes in science is “form and function” (National Research Council, 1996, p. 104). A “form” is any physical characteristic of an object or organism such as shape, pattern, color, size, configuration, flexibility, toughness, jointing, motion, texture, or luster. “Function” refers to the purpose or use of the object or organism or one of its parts. Form and function combinations work together when body parts of organisms, like animal legs and teeth or cactus spines and woody tree trunks, or parts of manufactured or human-made items are shaped, colored, textured, or configured to be physically suited to their purpose or use.

Choose some objects from the classroom, such as a stapler, pencil, and someone’s shoe. Practice having students identify the “forms” – any physical characteristic, including shape, color, size, texture, composition, flexibility, smoothness, pattern, luster (gloss or sheen), movement such as snapping or vibrating, sounds made such as clicking, etc. Then identify the function of the object. Discuss how the forms support the object’s function. See Table 2 for ideas. In this unit of activities, and in most diagrams and card sets, forms will be underlined and functions will be italicized to help students better distinguish them.
Table 2. Forms and Functions of Three Common Objects

<table>
<thead>
<tr>
<th>Object</th>
<th>Forms</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stapler</td>
<td>Color: black</td>
<td>Allows stapler to fit into any office décor’s color scheme</td>
</tr>
<tr>
<td></td>
<td>Surface texture: smooth</td>
<td>Pleasant to hold in the hand; easily wiped clean of dirty fingerprints</td>
</tr>
<tr>
<td></td>
<td>Configuration: hinged top part</td>
<td>Able to pivot to crunch down on paper</td>
</tr>
<tr>
<td></td>
<td>Configuration: top opens</td>
<td>Able to load staples inside</td>
</tr>
<tr>
<td></td>
<td>Composition: metal</td>
<td>Durable so it lasts a long time</td>
</tr>
<tr>
<td></td>
<td>Sound: clicks</td>
<td>Indicates when stapling is complete</td>
</tr>
<tr>
<td></td>
<td>Motion: snaps down</td>
<td>Puts pressure on staple to bend it</td>
</tr>
<tr>
<td>Pencil</td>
<td>Shape: cylindrical and long</td>
<td>Allows it to be comfortably gripped in hand</td>
</tr>
<tr>
<td></td>
<td>Texture: smooth</td>
<td>Allows wood to be ground off as graphite is used. Soft graphite rubs off on paper to make a mark</td>
</tr>
<tr>
<td></td>
<td>Soft graphite in center</td>
<td>Allows sharp lines or writing to be drawn</td>
</tr>
<tr>
<td></td>
<td>Pointed tip</td>
<td>Allows graphite mistakes to be removed</td>
</tr>
<tr>
<td></td>
<td>Flexible rubber eraser end</td>
<td></td>
</tr>
<tr>
<td>Running Shoe</td>
<td>Holes with metal rims</td>
<td>Allow shoe to be laced to adjust fit; metal keeps holes from tearing</td>
</tr>
<tr>
<td></td>
<td>Rubbery plastic sole</td>
<td>Cushions foot; waterproof and durable</td>
</tr>
<tr>
<td></td>
<td>Colorful with patterns of different shapes and colors</td>
<td>Attractive and status-symbol</td>
</tr>
<tr>
<td></td>
<td>Textured sole</td>
<td>Allows shoe to grip the surface for traction</td>
</tr>
</tbody>
</table>

Expansion:

1st Activity: Ask students to work in small groups of 2, 3, or 4 persons. Each group should secretly choose a different object present in the room and identify its forms and functions. Groups present a form or function of their object to the class and ask class members to guess the object. After each guess, present another clue until the object has been correctly identified. Students may want to use the strategy of presenting a form that is present in many objects in the room to make the game more challenging.

2nd Activity: Students bring in two objects from home (or found in the classroom) that have the same function. Make a chart to analyze the forms present in the objects as a way of evaluating which object serves the function best. Discuss findings with the class.
Lesson 2

Forms and Functions of the Human Hand

**Objective:** Students will be able to name forms and functions of the hand and relate them to tools and inventions.

**Exploration:** List parts of the human hand, such as thumb, fingers, knuckles, wrist, fingernails, palm. Have students tell the forms of the fingers. Possible responses include: long and thin, have joints to bend, attached to palm of hand, work together, thumb can meet fingers for pinching, fingers can curl around an object to grasp, skin-covered, and with nails for protection, scratching, digging.

Have students tell the functions of the hands (“Name things that you can do with your hands”). If a student names a very specific task, the teacher should generalize it. For example, if a student says, “You can make biscuits with hands,” the teacher can generalize that as holding items like rolling pins and pushing/pinching things like dough. Other generalized functions might be: grasp items, pull things toward person, push things away, dig, pat things, scratch a surface, rub things, roll things between fingers, pick up items, support body when crawling, signal other people, smooth a surface, pick small things out of a tangle or mass, and attract attention, among others.

**Explanation:** Make the connection as to why the hand can do these things. What forms (“What physical characteristics?”) of the hand help it scratch? The fingernails are tough and sharp; the hand can move to reach different areas; the fingers can bend and move to scratch. What forms of the hand allow signaling? The broad flat palm and fingers and the wrist joint allows motion.

Name activities that people can do somewhat with their hands, but might like to find a way to do better such as reach into pot of hot water, hold water for a drink, dig a hole in the garden, or draw with paints – finger-paint.

What do people do about these problems? (They invent tools/ other items). Name some tools that extend the actions of the hands. Name things that you wear on the hand or hold with the hand, such as shovel, trowel, spoon, cup, ladle, clothespin, flag, jewelry, or false fingernails).

Use Card Set 1, found in the Appendix. This set contains 14 sets of 4 cards each and header cards. Print the card set in color and mount it on cardboard. Cut apart into individual cards. Give each small group of students a set of the cards that have been mixed so they are not
in the correct order. Ask them to make an arrangement of rows and columns – a large chart. Each row should show a form, function, example action and example tool that all go together.

Figure 1. Card Set 1, Forms and Functions of the Hand with Analogous Manufactured Tools, Correctly Arranged as a Chart

![Form of the Hand](image1)

**Form of the Hand**

- Fingers can bend around the edge of an object in the palm.

**Function**

- Keep object from falling out of palm.

**Example Action**

- Loosely holding a hot dog sandwich.

**Example Tool**

- A tray is has raised edges to loosely hold cups in place.

---

**Form**

- Closed fist can be pressed against something.

**Function**

- Supporting the weight to steady the object.

**Example Action**

- Relaxed neck muscles while thinking.

**Example Tool**

- A pillow to supports the head, allowing rest.

---

**Form**

- Hand is planar with flat palm and fingers fanned out.

**Function**

- Broad surface for visibility.

**Example Action**

- Waving and signaling.

**Example Tool**

- Flag that is waved to signal.

---

**Form**

- Hand is planar with flat palm and fingers held together.

**Function**

- Broad surface to produce noise.

**Example Action**

- Clapping to show approval or gain attention.

**Example Tool**

- Cymbals to clang together.

---

**Form**

- Two fingers can be raised while others are curled.

**Function**

- Symbolizing: sending message.

**Example Action**

- Signifying victory to others.

**Example Tool**

- Badge to symbolize ideas.

Figure 1 (Continued). Card Set 1, Forms and Functions of the Hand with Analogous Manufactured Tools, Correctly Arranged as a Chart
Invention through Form and Function Analogy by Audrey C. Rule
Expansion: Create a class chart of student ideas concerning form and function of the hand and tools that extend these functions. Table 3 shows ideas that the teacher might suggest if student thinking becomes stalled. Use the same column headings.

Table 3. Suggestions for Forms and Functions of the Human Hand

<table>
<thead>
<tr>
<th>Form</th>
<th>Function</th>
<th>Example Action</th>
<th>Example Tool or Extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand can be planar when stretched with flat palm and fingers held together</td>
<td>Broad surface for visibility</td>
<td>Waving, signaling “Stop”</td>
<td>Foam hand used as sports games; day-glow police officer’s glove for traffic signaling</td>
</tr>
<tr>
<td></td>
<td>Broad surface to spread impact</td>
<td>Slapping a person when under attack; smoothing a surface while folding laundry; pushing against water while swimming; fanning air to cool off</td>
<td>Paper fan for circulating air; rolling pin to flatten dough; swim fins for swimming; leather baseball glove for catching balls</td>
</tr>
<tr>
<td></td>
<td>Broad surface to produce maximum noise</td>
<td>Clapping hands for applause or attention; playing a bongo drum</td>
<td>Cymbals to clang together</td>
</tr>
<tr>
<td>Flat surface to reach in a crevice</td>
<td>Edge of flat surface strikes with large force in a linear area</td>
<td>Feeling beside couch cushion to retrieve lost object. Karate chop; hand motion to cut through dough</td>
<td>Narrow attachment on vacuum cleaner for reaching crevices Knife for cutting</td>
</tr>
</tbody>
</table>
# Table 3 (Continued). Suggestions for Forms and Functions of the Human Hand

<table>
<thead>
<tr>
<th>Form</th>
<th>Function</th>
<th>Example Action</th>
<th>Example Tool or Extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand has joints and muscles to change configuration</td>
<td>Change shape to press differently into a surface or mold a surface</td>
<td>Working with dough or clay or finger paint</td>
<td>Sculpting tools, thicker paints</td>
</tr>
<tr>
<td>Fingers are jointed and work together</td>
<td>Fingers can curl around an object</td>
<td>Holding the handle of a suitcase or umbrella; holding cup or mug handle</td>
<td>Straps for attaching purse, backpack; gripper handle on apparatus that picks up objects from floor or shelves</td>
</tr>
<tr>
<td>Fingers have tough and pointed nails at the tips</td>
<td>Protect the fingertips</td>
<td>Fingernails protect the fingertips from damage when pinched or stepped-on. People pick off dirt with their fingernails</td>
<td>Touch gloves to protect fingers; finger guards on items such as paper cutters Scrubber pads for cleaning pots and pans or scrubber sponge for floors False or press-on nails, colored polish, decals, glitter</td>
</tr>
<tr>
<td>Fingers have tough and pointed nails at the tips</td>
<td>Scratch into a surface</td>
<td>People buff, trim, and groom fingernails to gain attention and look attractive</td>
<td></td>
</tr>
<tr>
<td>Attract visual attention</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thump can move to meet fingers</td>
<td>Pincer grip for grasping objects</td>
<td>Holding a book or pencil; picking up small items</td>
<td>Clasp, paper clip, binder clip for set of papers; clothespins</td>
</tr>
<tr>
<td>One or more fingers can be raised</td>
<td>Signaling; symbolizing</td>
<td>Pointing with index finger; making the peace sign, a “V” for victory; Spock’s Vulcan sign</td>
<td>Pins, medallions, tee-shirts, signs with symbols and messages</td>
</tr>
<tr>
<td>Move fingers independently</td>
<td>Operate mechanical devices or musical instruments</td>
<td>Keyboarding and typing; playing piano or musical instruments</td>
<td>Voice recognition software for translating speech into typing; music CD’s</td>
</tr>
<tr>
<td>Grasp and move fingers at same time</td>
<td>Hold onto item while doing an operation</td>
<td>Knitting, crocheting</td>
<td>Automatic knitting/weaving machines - looms</td>
</tr>
<tr>
<td>Palm, fingers, and thumb can form cup-shape</td>
<td>Holding liquid or loose grains</td>
<td>Cupping hand to drink water from a bowl or stream</td>
<td>Drinking cups, mugs, glasses; scoops, ladles</td>
</tr>
<tr>
<td>Fingers and thumb can be curled into a fist</td>
<td>Concentrate mass of the hand into a ball</td>
<td>Pounding a drum, pounding fist on surface for attention; punching an opponent; striking a large ball in sports</td>
<td>Drumsticks; gavel for judge or chair of a committee; punching glove, brass knuckles; sports racket</td>
</tr>
<tr>
<td>Skin of hand is elastic and covers hand completely</td>
<td>Protects hand from abrasion, sun’s rays</td>
<td>Protects against bumps and minor scratches</td>
<td>Protective work or gardening gloves</td>
</tr>
<tr>
<td>Fingers can be firmly held apart with fingers slightly curved</td>
<td>Sifting or combing</td>
<td>Combing through tangled hair; sifting pebbles from sand</td>
<td>A strainer used to sieve berries or a comb to comb hair</td>
</tr>
<tr>
<td>Skin of hands is soft</td>
<td>When hand rubs face or body it does not scratch</td>
<td>Washing face; giving backrub; brushing dirt or insects off body</td>
<td>Washcloth, towel; backrub/ massage tools; sponges</td>
</tr>
</tbody>
</table>
Table 3 (Continued). Suggestions for Forms and Functions of the Human Hand

<table>
<thead>
<tr>
<th>Form</th>
<th>Function</th>
<th>Example Action</th>
<th>Example Tool or Extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fingers have ridges in skin, or fingerprints</td>
<td>Gripping a surface</td>
<td>Gripping a jar as it is opened</td>
<td>Textured rubber pad for opening jars</td>
</tr>
<tr>
<td>Skin of hand darkens with sun exposure</td>
<td>Protects from sunburn</td>
<td>Hands of people who work outside are dark to prevent sunburn</td>
<td>Sunscreen; gloves</td>
</tr>
<tr>
<td>Index finger can be extended</td>
<td>Concentrate pressure/attention at one point</td>
<td>Pressing a button; pointing to an item of interest</td>
<td>Pointer, lever</td>
</tr>
</tbody>
</table>

As a culmination of the work in this lesson, ask students to trace around a hand on a piece of paper or provide a clipart hand printed on paper or in a file. Close to or on top of the sketch of the hand, label its forms. Then draw 5 tools/items around the hand that extend the forms and functions of the hand. Tell the function of each tool and connect it to one of the forms of the hand. See Figure 2.

**Figure 2. Drawing of Hand with Forms, Functions, and Tools that Extend these Actions**
Objective: Students will be able to name forms and function of the body that were extended by early inventions of humans.
Exploration: Remind students that many tools that are extensions of the form and function of the hand have been recently discussed. What other tools have people invented that extend other body parts?
Explanation: Ask students to share the ideas they generated. List parts of the human body (hands, arms, feet, legs, trunk, head, eyes, etc.) The Latin root of many words (manicure, manacles, or manual) is manus meaning hands. Humans can use their hands better than most other animals. Humans make tools to extend the functions of their hands (although a few animals also make tools – crows and chimps for example). Humans use their brains – their intelligence and imagination – to think of new ideas to make their lives easier. Besides extending the functions of the hand, some tools extended the functions of other body parts.

Name some tools that early humans invented (stone knives, spearheads, digging sticks, fire, and clothing). Pass around stone tools if possible or show images of them. Tell the function of each item and tell how it is an extension of a human body part (knives- cutting like teeth or fingernails; spearhead puncture like teeth or fingernails; digging stick to dig like fingers; fire and clothing to keep warm like hair and skin). Name other tools or items early humans invented to make their lives easier (pottery, different home styles such as skin tents, bags or pouches for carrying items, baskets, rugs).

Use Card Set 2 of the Appendix, Early Artifacts and Tools as Extensions of Forms of the Human Body, available in the Appendix. This card set contains 14 sets of 3 cards each that should be arranged to form a large chart of 14 rows and 3 columns. Figure 3 shows the cards correctly arranged into a chart; the order of the rows does not matter.
**Figure 3. Card Set 2, Early Artifacts and Tools as Extensions of Forms and Functions of the Human Body**

<table>
<thead>
<tr>
<th>Artifact and Form</th>
<th>Function of the Tool</th>
<th>Human Body Part Extended</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Image" /></td>
<td><strong>A drum has a broad top surface that resonates and makes a loud sound when slapped.</strong></td>
<td><strong>Slapping one's thighs with flattened palms to make a rhythmic noise.</strong></td>
</tr>
<tr>
<td><img src="image2" alt="Image" /></td>
<td><strong>Blowing into a hollow reed flute causes the reed to vibrate.</strong></td>
<td><strong>Blowing through mouth and vibrating the lips to produce whistles.</strong></td>
</tr>
<tr>
<td><img src="image3" alt="Image" /></td>
<td><strong>A stone knife has a fairly flat top and bottom surface, but a sharp serrated edge all around.</strong></td>
<td><strong>Fists (for pounding); teeth (cutting and breaking apart).</strong></td>
</tr>
<tr>
<td><img src="image4" alt="Image" /></td>
<td><strong>A heavy stone axe head is block-shaped with a sharp tapered edge and a groove around all or most of the block.</strong></td>
<td><strong>Teeth cutting into something to break off a part.</strong></td>
</tr>
<tr>
<td><img src="image5" alt="Image" /></td>
<td><strong>The broad sharp edge is perfect for dragging across a hide to scrape off the layer of fat and for scraping dirt or skins from carrots or potatoes.</strong></td>
<td><strong>Fingernails (for scratching and scraping); teeth (scraping).</strong></td>
</tr>
</tbody>
</table>
Figure 3 (Continued). Card Set 2, Early Artifacts and Tools as Extensions of Forms and Functions of the Human Body

**Artifact and Form**
- An *arrowhead* is triangular in shape, with a point at the tip and sharp edges. Arrowheads often have notches at the base.

**Function of the Tool**
- The pointy end and sharp edges make it penetrate an animal’s or enemy’s body to *injure or kill it*. The notches allow the tool to be attached to a shaft.

**Human Body Part Extended**
- Fists (for punching); teeth for cutting.

---

**Artifact and Form**
- A strong stone *hoe* has a large, flat, tapering wedge-shaped rectangular shape with sharp edges.

**Function of the Tool**
- The strong wedge can be *pushed into the ground to dig* a hole for planting or remove weeds.

**Human Body Part Extended**
- Hands (for pushing into the ground).

---

**Artifact and Form**
- A leather or woven *pouch or bag* is lightweight, flexible, and made of readily-available materials. It can expand to hold more items.

**Function of the Tool**
- This tool functions as a *container to hold items*. It can expand or contract a bit to hold more or less.

**Human Body Part Extended**
- Hands (holding items).

---

**Artifact and Form**
- An *basket* is made of *straps of wood or plant stems woven together*. It is lightweight and hollow. It may have a lid or cover.

**Function of the Tool**
- The hollow nature of this item allows it to *hold or contain items* like seeds, berries, and other foods or personal items.

**Human Body Part Extended**
- Hands (holding items).

---

**Artifact and Form**
- A *blanket* is a broad flat layer made of soft skins or woven fabric. It is flexible and can be wrapped or arranged in many shapes.

**Function of the Tool**
- The fibrous layer is used to *trap body heat* or to insulate/protect a person from dampness or cold.

**Human Body Part Extended**
- Like having a thicker skin or more hair.

---

**Artifact and Form**
- A *stone drill* is a fairly small tool with a long, sharp pointed end.

**Function of the Tool**
- This tool is turned or twisted on a surface to *bore a hole* in that surface.

**Human Body Part Extended**
- Fingernails scratching a hole in something.
### Expansion:

**1st Activity:** Ask students to develop a chart that lists early artifacts or tools used by people, their functions, and the human body part that is extended. Table 4 shows suggested ideas.

**Table 4. Early Artifacts, their Functions and the Human Body Part Extended by the Tools**

<table>
<thead>
<tr>
<th>Artifact</th>
<th>Function</th>
<th>Human Body Part Extended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone arrowhead</td>
<td>Shooting and killing animals for food</td>
<td>Teeth (biting) or fingernails (scratching) or fist (punching)</td>
</tr>
<tr>
<td>Stone scraper chipped tool</td>
<td>Cleaning animal hides to make blankets, clothing, tents</td>
<td>Fingernails (scraping), teeth (scraping and biting)</td>
</tr>
<tr>
<td>Stone knife chipped tool</td>
<td>Cutting food, cutting branches, cutting animal skins</td>
<td>Teeth (cutting), fingers (tearing and ripping)</td>
</tr>
<tr>
<td>Stone hoe or digging stick</td>
<td>Planting seeds or removing weeds</td>
<td>Fingers (probing and scratching ground)</td>
</tr>
<tr>
<td>Woven blanket, animal hides</td>
<td>Trapping heat to keep body warm; protecting body from hard surfaces</td>
<td>Like having a thicker skin or more hair</td>
</tr>
</tbody>
</table>
Table 4 (Continued). Early Artifacts, their Functions and the Human Body Part Extended by the Tools

<table>
<thead>
<tr>
<th>Artifact</th>
<th>Function</th>
<th>Human Body Part Extended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pottery bowl</td>
<td>Storing, cooking, carrying items</td>
<td>Like an extra hand to hold things</td>
</tr>
<tr>
<td>Fabric or leather pouch or bag</td>
<td>Storing, carrying items</td>
<td>Like an extra hand to hold things</td>
</tr>
<tr>
<td>Hat with brim or visor</td>
<td>Keep sun or rain out of eyes</td>
<td>Like holding hand over eyes</td>
</tr>
<tr>
<td>Sandals</td>
<td>Protect the feet from cuts, injury</td>
<td>Like having thicker skin</td>
</tr>
<tr>
<td>Stick</td>
<td>Drawing in dirt or sand</td>
<td>Finger</td>
</tr>
<tr>
<td>Woven basket</td>
<td>Storing, carrying items</td>
<td>Like an extra hand to hold things</td>
</tr>
<tr>
<td>Wooden staff</td>
<td>Steady a person while walking on uneven ground</td>
<td>Like having an extra leg for stability</td>
</tr>
<tr>
<td>Rope</td>
<td>Pulling an item or suspending an item from a height</td>
<td>The arms</td>
</tr>
<tr>
<td>Flat grinding stones</td>
<td>Grinding grains to make breads</td>
<td>Teeth (grinding)</td>
</tr>
<tr>
<td>Bullroarer</td>
<td>Sending warnings or other signals</td>
<td>Voice used in calling</td>
</tr>
<tr>
<td>Strand of beads</td>
<td>Attract attention, mark status</td>
<td>Like having attractive and shiny eyes, teeth, and lips</td>
</tr>
</tbody>
</table>

2nd Activity: Bring in two items used by early humans that served similar purposes or functions. Perhaps one might bring a pottery jar/bowl and a basket as the two objects that were used for storage. Ask students to evaluate the two objects for the stated function, using forms of the object to support their ideas.
Objective: Students will be able to tell how various inventions/tools satisfy basic human needs.

Exploration: Ask students to name basic human needs. How do inventions help to satisfy human needs?

Explanation: Basic human needs are things all people need to survive, thrive, and reach their potentials: food, water, shelter, clothing, spirituality, entertainment. How do inventions help to satisfy human needs? What inventions help people grow, obtain, or process food? Possible responses are: tractor, plow, trucks, blender, and stove. What did early humans or groups of people with primitive technology do to satisfy these human needs? What modern inventions take the place of these earlier inventions? Make a chart similar to that shown in Table 3.

Table 5. Example Inventions of Early Humans and Modern People that Satisfy Basic Human Needs for Use with Lesson 4

<table>
<thead>
<tr>
<th>Basic Human Need</th>
<th>Inventions of Early Humans</th>
<th>Inventions of Modern Humans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food: Items for gathering seeds or plant materials</td>
<td>Baskets, hollow gourds, pottery bowls, jars</td>
<td>Plastic, glass and ceramic containers/dishes; tractors for harvesting</td>
</tr>
<tr>
<td>Food: Items for capturing wild game animals</td>
<td>Fish nets, hooks; spears, bows, arrows; pit traps</td>
<td>Guns, fishing rods</td>
</tr>
<tr>
<td>Food: items for processing grains and seeds</td>
<td>Mano and metate (flat grinding stone and grinding implement); stone knives</td>
<td>Blender, food processor, steel knives</td>
</tr>
<tr>
<td>Food: items for cooking</td>
<td>Campfire to heat stones put into pot to boil food</td>
<td>Electric or gas stove and metal pots; microwave oven, toaster</td>
</tr>
<tr>
<td>Clothing</td>
<td>Bone needle and animal sinew for sewing</td>
<td>Synthetic fibers such as nylon; sewing machines</td>
</tr>
</tbody>
</table>
Table 3 (Continued). Example Inventions of Early Humans and Modern People that Satisfy Basic Human Needs for Use with Lesson 4

<table>
<thead>
<tr>
<th>Basic Human Need</th>
<th>Inventions of Early Humans</th>
<th>Inventions of Modern Humans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food: utensils for eating</td>
<td>spoons, scoops, pottery bowls, gourds, shells</td>
<td>steel utensils, plastic picnic ware; bowls; fine china</td>
</tr>
<tr>
<td>Shelter: Warmth</td>
<td>campfire; hide or fur blankets, woven rugs; simple clothing</td>
<td>heated homes, space heater, elaborate clothing, parkas, boots, down comforters</td>
</tr>
<tr>
<td>Shelter: Safety from weather exposure</td>
<td>Caves, bark, hide or thatch-covered homes</td>
<td>Insulated brick or frame homes with windows; waterproof metal or shingled roofs</td>
</tr>
<tr>
<td>Shelter: Safety from animal/human enemy attack</td>
<td>Homes, spears, groups of warriors</td>
<td>Fences, durable modern homes, security systems, lighting systems; police force, militia</td>
</tr>
<tr>
<td>Food: preservation for time of shortage</td>
<td>Salting or drying foods</td>
<td>Freezers</td>
</tr>
<tr>
<td>Safety: Fighting enemies or wild animals</td>
<td>Club made of bone or wood</td>
<td>Fences, door locks, security systems</td>
</tr>
<tr>
<td>Entertainment/Spirituality: Music</td>
<td>Rattles from shell, gourds, turtle shells; flutes from hollow bones, reeds, shell; drums from hide stretched over a hollow log or similar</td>
<td>Modern musical instruments; recorded music on CD’s; radio; iPods</td>
</tr>
<tr>
<td>Self Esteem: Personal Adornment</td>
<td>Clay and iron minerals (hematite, limonite) for face paint; Carved bone or wooden combs; sharpened clam shell for shaving; necklaces of shells, seeds, beads</td>
<td>Modern make-up and cosmetics; soaps; modern razors, plastic costume jewelry; Metallic or sequined fabrics</td>
</tr>
<tr>
<td>Hygiene: Disposal of human waste</td>
<td>Digging a simple pit toilet</td>
<td>Modern flush toilets with seats</td>
</tr>
<tr>
<td>Communication</td>
<td>Smoke signals or drumming</td>
<td>Cell phones</td>
</tr>
<tr>
<td>Communication: Dances and Performances</td>
<td>Dance costumes with feathered headdresses, decorated capes, a fire for lighting</td>
<td>Dance costumes of synthetic materials; loudspeakers, stage lighting; printed programs</td>
</tr>
<tr>
<td>Communication: Historical records</td>
<td>Cave drawings; drawings on rock (petroglyphs and pictographs) drawings on skins, knotted ropes, designs on pottery wood</td>
<td>Books, ledgers, computer files, public records in public buildings, libraries, film and digital photographs, movies</td>
</tr>
</tbody>
</table>
Expansion:

1st Activity: Use Card Set 3. This set contains 20 sets of 3 cards each plus heading cards for the three columns. Print the card set in color and mount on cardboard. Cut apart into individual cards. Give each small group of students a set of the cards. Ask them to make an arrangement of rows and columns – a large chart. The chart rows should look like the chart in Figure 4.

Figure 4. Card Set 3, Early and Modern Inventions that Serve Basic Human Needs
Figure 4 (Continued). Card Set 3, Early and Modern Inventions that Serve Basic Human Needs

<table>
<thead>
<tr>
<th>Basic Human Need</th>
<th>Early Invention</th>
<th>Modern Invention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shelter:</strong> Heat source to protect self from cold weather</td>
<td>Campfire</td>
<td>Furnace, space heater</td>
</tr>
<tr>
<td><strong>Clothing:</strong> Insulating body coverings for warmth or protection from weather</td>
<td>Hide or fur blankets, woven cloth clothing/robes</td>
<td>Machine-woven blankets, fitted clothing, synthetic fabrics</td>
</tr>
<tr>
<td><strong>Shelter:</strong> Insulating structure to protect from rain and weather extremes</td>
<td>Caves and skin, bark, or thatch-covered homes</td>
<td>Insulated brick or frame homes</td>
</tr>
<tr>
<td><strong>Food:</strong> Dishes and utensils for serving and eating</td>
<td>Spoons, scoops, pottery bowls, gourds, shells</td>
<td>Steel utensils, plastic picnic ware; bowls; fine china</td>
</tr>
<tr>
<td><strong>Communication:</strong> Sounds, rhythms and music to communicate mood</td>
<td>Rattles from shell, gourds, turtle shells; flutes from hollow bones, reeds</td>
<td>Modern musical instruments; recorded music on CD’s; radio; iPods</td>
</tr>
<tr>
<td><strong>Communication through Clothing:</strong> Elaborate, symbolic costumes for ceremonies</td>
<td>Costumes with feathers, flowers, shells, wooden decorations</td>
<td>Costumes with glittery fabrics, synthetic beads</td>
</tr>
</tbody>
</table>
Figure 4 (Continued). Card Set 3, Early and Modern Inventions that Serve Basic Human Needs

<table>
<thead>
<tr>
<th>Basic Human Need</th>
<th>Early Invention</th>
<th>Modern Invention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety:</strong> Armed humans for protection from animal/enemy attack</td>
<td>Warriors with spears</td>
<td>Police with guns, army personnel</td>
</tr>
<tr>
<td><strong>Self Esteem and Communication:</strong> Colorful paint applied to the face to communicate mood, status or improve appearance</td>
<td>Paint made of ground hematite or ochre mixed with oil and applied to face</td>
<td>Modern cosmetics in many colors</td>
</tr>
<tr>
<td><strong>Communication:</strong> Lasting records of events to communicate group history</td>
<td>Petroglyphs, pictographs, drawings on leather, carved records</td>
<td>Books, ledgers, computer files, films</td>
</tr>
<tr>
<td><strong>Transportation:</strong> Vehicles that can carry people and supplies for travel through snow</td>
<td>Wooden sled pulled behind the person</td>
<td>Motorized snowmobiles</td>
</tr>
<tr>
<td><strong>Transportation:</strong> Vehicles that can carry people and supplies for travel through water</td>
<td>Canoes made of hollow trees or birch bark</td>
<td>Motor boats</td>
</tr>
<tr>
<td><strong>Transportation:</strong> Apparatus or vehicle for transporting young children</td>
<td>Papoose or cradleboard for carrying child on back</td>
<td>Baby carriages</td>
</tr>
</tbody>
</table>
2nd Activity: Ask students to create a collage with the individual student at the center surrounded by basic human needs. The student should find clip art, magazine photos, or take photographs to illustrate an invention that he or she uses to serve teach basic need.
Lesson 5

Invention through Form and Function Analogy

Tools Related to Forms and Functions of the Mouth

Objective: Students will be able to name ways the functions of the mouth are extended by tools and inventions.

Exploration: Ask students to list tools that they think are extensions of the mouth.

Explanation: List parts of the mouth (lips, tongue, teeth). Tell the forms of these parts and their functions. Teeth are hard, durable, fitting together and have grinding action to chew food. Tongue is very flexible and muscular to push food and clean teeth. Lips are elastic, can purse and change shape to make speech, whistle, and noises, to communicate, to suck up liquid. Create a chart with the following columns: form, function, example action, and example gadget from a catalog that is an extension of the form and function of the mouth.

Table 6. Forms and Functions of the Human Mouth with Gadgets that Extend Them

<table>
<thead>
<tr>
<th>Form</th>
<th>Function</th>
<th>Example Action</th>
<th>Example Gadget or Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front teeth are sharp and chisel-like</td>
<td>Biting into and piercing; tearing</td>
<td>Biting a chunk off an apple; tearing a piece of cloth or opening a sealed plastic bag of chips</td>
<td>Knives</td>
</tr>
<tr>
<td>Back teeth have hard, tough, broad surfaces</td>
<td>Crushing and grinding</td>
<td>Chew peanuts into a smooth paste for swallowing</td>
<td>Mortar and pestle</td>
</tr>
<tr>
<td>Mandibular joint of jaw allows up and down and sideways motions</td>
<td>Crushing and grinding</td>
<td>Chewing grapes to extract juice and grind skins</td>
<td>Juicer or food processor</td>
</tr>
<tr>
<td>Tongue is strong and flexible</td>
<td>Push food around the mouth; clean teeth</td>
<td>Push peanut butter off roof of mouth, push seeds from between teeth</td>
<td>Toothpicks, toothbrush</td>
</tr>
</tbody>
</table>
Table 6 (Continued). Forms and Functions of the Human Mouth with Gadgets that Extend Them

<table>
<thead>
<tr>
<th>Form</th>
<th>Function</th>
<th>Example Action</th>
<th>Example Gadget or Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tongue is long enough to extend outside the mouth</td>
<td>Licking, cleaning</td>
<td>Lick face area around mouth clean; lick popsicle</td>
<td>Washcloth; individual wipes in sealed pouches</td>
</tr>
<tr>
<td>Tongue changes shape and presses against different parts of mouth</td>
<td>Different sounds are produced</td>
<td>Speaking</td>
<td>Cell phone; loudspeaker; party horns; harmonica; flute</td>
</tr>
<tr>
<td>Lips are elastic and can open and close tightly</td>
<td>Closing the mouth</td>
<td>Keep bugs out of mouth</td>
<td>Hat with net that extends over face</td>
</tr>
<tr>
<td>Teeth are sharp and jaws can move to shear teeth against each other</td>
<td>Tearing and shredding</td>
<td>Biting and shredding foods</td>
<td>Paper shredder</td>
</tr>
<tr>
<td>Mouth is hollow and lips can close the opening</td>
<td>Hide a secret item in the mouth</td>
<td>Hiding gum, candy, or a coin</td>
<td>Fanny pack, pocket, or wallet</td>
</tr>
<tr>
<td>Lips change shape</td>
<td>Produce sounds</td>
<td>Whistling; making “raspberry” sounds when joking</td>
<td>Whoopee cushion</td>
</tr>
<tr>
<td>Upper throat has large opening</td>
<td>Air passageway</td>
<td>Allows breath to be expelled from lungs for blowing up a balloon</td>
<td>Balloon pump</td>
</tr>
</tbody>
</table>

Expansion:

1st Activity: Provide many gadget catalogs (travel gadget catalogs from airplanes are great) for students to cut apart. Ask students to find and cut out items that extend the functions of the hand or mouth or feet (choose one of these). Draw the body part in the middle of your paper. Paste the gadgets, tools, or items around it. On a line connecting the item to the body part, tell the form and function that makes this item an extension of the body part.

2nd Activity: Ask students to create their own invention that is an extension of the mouth. First, they should determine a need that they want to satisfy with the invention. Provide a box of recycled items and craft materials such as paper, aluminum foil, chenille sticks, and Popsicle sticks. Allow students to make their own version of an invention available as a manufactured item. For example, students may want to create a flute, whistle, or a nutcracker.
Objective: Students will be able to place inventions related to the same concept in chronological order and to tell advantages and limitations.

Exploration: Ask students to name some inventions that have been improved over the years and to list limitations, advantages, and improvements.

Explanation: Begin by discussing how things change overtime. Ask if anyone has videotaped movies at home. Many movies at theaters are still projected from film. Ask what other form movies take now – often on DVD’s. More recently, movies are digital files sent over the web. So, movies started as films, then tapes, then DVD’s and now digital files. Each time the way movies are stored changed and improvements were made. Films are large and bulky and often break. One needs a large projector to show them. Video tapes were an improvement because they are smaller and utilized less expensive equipment. DVD’s were an improvement over videotapes because the tapes could not break and they were small disks that were easier to store. Having a digital file on your computer makes storage and playing even easier.

Define terms: a limitation is a restriction, weakness, or drawback; an advantage: a favorable characteristic that contributes to success of the product; an improvement is a change that brings an advancement in excellence.

Implement the sets of materials of Card Set 4. Each group receives a packet of pictures of related inventions with their forms and functions to be placed in time order from earliest (from a long time ago) to most recent (now). Figure 5 shows the answers in correct order. Then students place cards that tell the advantages and limitations, matching them to the correct inventions. This allows students to recognize the driving force behind new innovations to improve the product and get rid of limitations. This also shows how we should appreciate those who came before us to create these wonderful inventions. After a group has explored one set of materials, mix and rotate the materials so everyone gets to experience inventions in the sets.
Invention through Form and Function Analogy by Audrey C. Rule

Figure 6. Card Set 4, Technological Changes to a Product through Time

<table>
<thead>
<tr>
<th>Addition Tools</th>
<th>Counting on fingers</th>
<th>Notches on a stick or knots on a rope</th>
<th>Base ten numerals written on surface</th>
<th>Abacus</th>
<th>Mechanical adding machine or slide rule</th>
<th>Electronic calculator</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Form and Function</strong></td>
<td>Fingers move and are raised to keep track by counting all.</td>
<td>Notches or knots represent numbers for counting.</td>
<td>Numerals serve as mnemonics during mental addition.</td>
<td>Beads on a frame are moved to calculate sums.</td>
<td>Mechanical parts that slide or gears that turn calculate a sum.</td>
<td>Computer chip electronically calculate the sum.</td>
</tr>
<tr>
<td><strong>Advantages:</strong></td>
<td>Attached to body, so readily available.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Limitations:</strong></td>
<td>Only have 10 fingers. No way to preserve final sum.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Writing Pens</th>
<th>Duck or goose quill and ink well</th>
<th>Metal pen tip that fit into a pen holder</th>
<th>Fountain pen with nib and refillable ink cartridge</th>
<th>Ball-point pen</th>
<th>Felt-tip and soft-tip pens</th>
<th>Rollerball pens</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Form and Function</strong></td>
<td>Tough, hollow tube that can be shaped to form a pen point and dipped in ink.</td>
<td>Strong, durable metal pen tip used with ink for writing.</td>
<td>Hollow plastic cylinder contains inner cartridge of ink to supply tip.</td>
<td>Ball-shaped writing tip turns in a socket to roll and write; thick ink is used to prevent leakage.</td>
<td>A felt or porous plastic tip allows ink to flow from reservoir to allow easy writing.</td>
<td>A ball-shaped tip writes smoothly; a wick draws the ink from a reservoir to prevent leakage.</td>
</tr>
<tr>
<td><strong>Advantages:</strong></td>
<td>A natural material readily available. Hollow tube holds ink to write a couple of words.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Limitations:</strong></td>
<td>Tip wears out in a week and must be re-shaped.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Advantages: One can make calculations by writing on the paper or bark. Limitations: Must do a lot of mental calculation.


Advantages: No errors if operated properly. Fast and can handle large numbers. Limitations: Human operated. Limited number size.

Advantages: High speed; high accuracy; can handle very large numbers. Limitations: Data input by hand.
## Figure 6 (Continued). Card Set 4, Technological Changes to a Product through Time

### Cooking

<table>
<thead>
<tr>
<th><strong>Cooking</strong></th>
<th><strong>Form and Function</strong></th>
<th><strong>Advantage</strong></th>
<th><strong>Limitations</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Campfire in rock circle</td>
<td>Smoky, burning wood fire contained by rock circle for heat and cooking.</td>
<td>Simple to construct from natural materials.</td>
<td>Smoky and difficult to control – may send out sparks.</td>
</tr>
<tr>
<td>Fireplace with iron tools</td>
<td>Wood-burning fire in a stone or brick arched area for containment with a chimney for smoke.</td>
<td>Part of a house – provides heat to home. Contained on three sides and use screen to stop sparks.</td>
<td>Smoky at times.</td>
</tr>
<tr>
<td>Pot-bellied or cast-iron stove</td>
<td>Cast-iron container to radiate heat with a flat top for cooking attached to a chimney or stove pipe for smoke.</td>
<td>Fire is contained, much less smoke; top surface for cooking; heats home.</td>
<td>Must start fire and load with wood.</td>
</tr>
<tr>
<td>Gas stove with burners</td>
<td>Metal stove attached to gas line or gas cylinder for fuel. Burners on top direct fire to bottom of pots or pans.</td>
<td>Can light with a match. Easy to turn on and off. No need to gather fuel. No smoke.</td>
<td>Fire danger if elements are left on.</td>
</tr>
<tr>
<td>Electric stove</td>
<td>Stove with electric wiring; for smokeless and flameless fuel; coiled elements deliver heat without flame.</td>
<td>Can easily start and stop; less danger of fire.</td>
<td>Fire danger if elements are left on.</td>
</tr>
<tr>
<td>Microwave oven</td>
<td>A box-like oven protects people from microwaves; Microwaves excite water molecules to produce heat.</td>
<td>Food cooks much faster; cold food can be easily re-heated.</td>
<td>Cannot use metal containers.</td>
</tr>
</tbody>
</table>

### Bathing

<table>
<thead>
<tr>
<th><strong>Bathing</strong></th>
<th><strong>Form and Function</strong></th>
<th><strong>Advantage</strong></th>
<th><strong>Limitations</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wash self in stream</td>
<td>Natural outdoor stream with cold rushing current so that water washes away dirt.</td>
<td>Stream water is often readily available without preparation.</td>
<td>Little privacy, no soap, water is cold.</td>
</tr>
<tr>
<td>Use pottery basin and pitcher and take a sponge bath</td>
<td>Cold water from pitcher poured in basin for washing indoors in privacy.</td>
<td>Washing can be done in privacy.</td>
<td>Must fill and empty pitcher and basin. Generally the water is cold.</td>
</tr>
<tr>
<td>Hand-pump water to sink for washing; heat water on stove for metal/wood tub.</td>
<td>Cold water from pitcher poured in basin for washing indoors in privacy.</td>
<td>Water heated on the stove makes the bath warmer.</td>
<td>Must fill and empty heavy tub of water.</td>
</tr>
<tr>
<td>Bathtub filled with running water; must still heat water on stove.</td>
<td>Cold water flows from tap. Extra water must be heated on stove to adjust the temperature.</td>
<td>Cold running water requires little effort to fill and drain tub.</td>
<td>Warm water must still be heated on the stove.</td>
</tr>
<tr>
<td>Bathtub filled with warm or hot water from hot water heater.</td>
<td>Both cold and hot (from hot water heater) flow from tap for hot baths.</td>
<td>Both hot and cold running water and easy to drain tub.</td>
<td>No way to create wave action.</td>
</tr>
<tr>
<td>Built-in whirlpool bath or hot tub</td>
<td>Warm water and whirlpool action clean the body and soothe sore muscles.</td>
<td>Warm wave action soothes and cleanses the body.</td>
<td>Uses a lot of water and energy.</td>
</tr>
</tbody>
</table>
Figure 6 (Continued). Card Set 4, Technological Changes to a Product through Time

### Storage of Music

<table>
<thead>
<tr>
<th>Sheet Music</th>
<th>Mechanical Music Box</th>
<th>Phonograph Records</th>
<th>Magnetic Tape</th>
<th>Compact Disk</th>
<th>iPod</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Form and Function</strong></td>
<td>Symbols on parchment or paper interpreted and played by musicians using musical instruments.</td>
<td>A cylindrical rotating drum with small metal nubs play a repeating melody on larger mucial prongs.</td>
<td>A plastic disk with a long spiralling groove that vibrates a needle riding along the groove to produce music.</td>
<td>A long plastic, iron-coated tape passes by an electromagnet and is altered by a field caused by sound waves vibrating a wire coil on the magnet.</td>
<td>A thin disk of polycarbonate plastic impressed with bumps on a long spiral track is read by a laser and the data is converted to music.</td>
</tr>
</tbody>
</table>

**Advantage**: Can obtain a wide variety; easy to store.  
**Limitations**: Must know how to read music and play an instrument. Must have an instrument available.

**Advantage**: Anyone can play and replay.  
**Limitations**: The music is always played by one type of musical instrument.

**Advantage**: Plays all varieties of music. Can change records to hear different tunes.  
**Limitations**: Must have a studio to record. Player cannot be moved while playing.

**Advantage**: Highly portable instant recording/playback and erasing.  
**Limitations**: Wears out and breaks easily, especially if exposed to heat.

**Advantage**: Highly quality recordings last a long time.  
**Limitations**: A large collection takes up a lot of space.

**Advantage**: Thousands of recordings stored in small space.  
**Limitations**: Listening to loud music through ear buds may damage hearing.

### Weather Forecasting

<table>
<thead>
<tr>
<th>Observe Cloud Patterns</th>
<th>Kites used to Obtain Information</th>
<th>Weather Balloons</th>
<th>Telegraph Information from Upwind Areas</th>
<th>Weather Satellites</th>
<th>Computer Modeling of Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Form and Function</strong></td>
<td>People watch cloud patterns and recall the weather than usually follows.</td>
<td>A kite floats to the upper atmosphere to collect information to help predict the weather.</td>
<td>A weather balloon floats to the upper atmosphere to collect information to help predict the weather.</td>
<td>A telegraph brings information from upwind areas to help people see what is coming.</td>
<td>Satellites take wide-range photographs and collect temperature information to help predict the weather.</td>
</tr>
</tbody>
</table>

**Advantage**: Can perform without equipment.  
**Limitations**: Relies on memory; Not very accurate.

**Advantage**: Can sample air from higher levels.  
**Limitations**: Dangerous during storms; hard to control.

**Advantage**: Can go quite high and carry equipment for measurements.  
**Limitations**: Only samples air in one locality.

**Advantage**: Can determine the weather that is moving toward an area.  
**Limitations**: Harder to predict long-range weather.

**Advantage**: Photographs and temperature maps of large areas produced.  
**Limitations**: Expensive.

**Advantage**: Information is integrated and more accurate.  
**Limitations**: Weather is complex and difficult to model.
**Expansion:**

**1st Activity:** Students name modern items that had less-sophisticated predecessors. Encourage students to think not only of gadgets and appliances, but of furnishings, businesses, and processes. Tell the advantages of the new items. Tell any disadvantages or limitations.

*Predecessor:* something that came before and is now replaced by something else.

**Figure 7. Card Set 5, Common Items, Businesses, or Processes and their Predecessors**

<table>
<thead>
<tr>
<th>Predecessor</th>
<th>New Innovation</th>
<th>Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweeping the rug clean with a broom</td>
<td>Shampooing the rug with a rug cleaner</td>
<td>Dissolves dried-on dirt, Vacuums and sucks dirt away, Removes odors, No dust left</td>
</tr>
<tr>
<td>Heating home with fireplace</td>
<td>Heating home with furnace</td>
<td>Cleaner, no ash, smoke, Less work, No need to gather wood, Can easily adjust temperature</td>
</tr>
<tr>
<td>Using hair rollers for curly hair</td>
<td>Using a curling iron for curly hair</td>
<td>Faster, Easier, Can re-curl parts that are not curly enough</td>
</tr>
<tr>
<td>Candles for lighting</td>
<td>Electric fluorescent lighting</td>
<td>Instant on and off, More light, Cool, Little fire danger</td>
</tr>
<tr>
<td>Wild Strawberries</td>
<td>Huge Strawberries selectively bred</td>
<td>Much larger, Firm when ripe, Sweet-tasting, Last longer without rotting</td>
</tr>
</tbody>
</table>
**2nd Activity:** Students should choose an invention that has a long history of changes and research these. Students should prepare a chart similar to one of the sets of Figure 6. They should determine the advantages and limitations of each stage in the history of the invention.

**Figure 7 (Continued). Card Set 5, Common Items, Businesses, or Processes and their Predecessors**

| Simple manual toothbrush | Electric Toothbrush | More brush strokes
|  |  | Variable angle
|  |  | Easier to use because hand does not tire
| Home Remedy for Illness | Prescription Medicine | Powerful antibiotics kill germs
|  |  | Designed to target specific ailments
| Paper Grocery Bag | Re-usable Fabric Bag | Does not require cutting trees
|  |  | Reusable
|  |  | Stronger and more durable
|  |  | Has carrying handles
|  |  | More colorful
|  |  | Washable
| Metal grater for food shredding | Electric Food Processor | Less work for cook
|  |  | Can chop to desired sizes
|  |  | All food bits are contained
|  |  | none falling elsewhere
|  |  | Less risk of cutting fingers
| Mixing with a spoon | Electric Mixer | Faster
|  |  | Easier
|  |  | Mixes smoother
|  |  | Whips in more air
| Sending trash to a landfill | Recycling plastics, metal, paper | Less wasteful
|  |  | Saves energy
|  |  | Does not take up land space
|  |  | Less pollution of groundwater
Lesson 4. Form and function of animal body parts or animal-made homes and relationship to human manufactured items

Explore form and function analogy object boxes related to different animals. The available sets of materials (available in the Appendix) include:

- Alligator form and function analogy cards;
- Beaver form and function analogy cards;
- Bluebird form and function analogy cards;
- Owl form and function analogy cards;
- Whale form and function analogy cards; and
- Wolf form and function analogy cards.

Lesson 7 Activity 1 Matching Animal Forms and Function to Manufactured Items

**Objective:** Students will be able to identify the forms and functions of animal body parts or animal-made homes to identify human tools that have similar forms and functions.

**Procedure:** Card Set 6 contains sets of cards for six different animals. Students work with the cards for one animal at a time. They take out the one-sided manufactured object cards with an orange background color and place them face up on the work surface. These are the human-manufactured items that can be related through form and function analogies to the animal body parts or animal made homes. Students should then turn the 12 two-sided animal form and function cards to the side that shows an image of the animal or the animal home. Choose one of these cards. Read the animal form and function on the front of the card. Attempt to find a human manufactured item with the same form and function. Place that object card with the form and function card. Do not turn the form and function cards over until all cards have been paired with their corresponding objects. Then turn the cards over and check your work with the explanations on the backs.
Lesson 7 Activity 2. Mapping an Analogy

Objective: Students will be able to map the similarities and differences between animal body parts form and function and corresponding human tools.

Procedure: Take one animal form and function card from the card set. Map the similarities of the analogy and limits of the analogy for this one card. Example Figures and Tables follow that show one card from each set. (See Figures 7 through Figure 12 and Table 7 through Table 12).

Figure 8. Example Front (left) and Back of a Card (right) from the Alligator Set

Table 7. Mapping One of the Analogies for Alligator

<table>
<thead>
<tr>
<th>Similarities = Mapping the Analogy</th>
<th>Category</th>
<th>Boat Oar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alligator Tail</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tan-brown</td>
<td>Form: color</td>
<td>Tan-brown</td>
</tr>
<tr>
<td>Moves side to side in water</td>
<td>Form: motion</td>
<td>Pushes sideways in the water</td>
</tr>
<tr>
<td>Broad, flat</td>
<td>Form: shape</td>
<td>Broad, flat</td>
</tr>
<tr>
<td>Water repellant</td>
<td>Form: surface characteristics</td>
<td>Water repellant</td>
</tr>
<tr>
<td>Propel through water</td>
<td>Function</td>
<td>Propel through water</td>
</tr>
<tr>
<td>Steer in water</td>
<td>Function</td>
<td>Steer in water</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Differences = Limits of the Analogy</th>
<th>Category</th>
<th>Boat Oar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alligator Tail</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Always a natural alligator skin color of browns or greens</td>
<td>Form: color</td>
<td>May be a natural wood color or may be painted or even made of plastic</td>
</tr>
<tr>
<td>Alligator hide and flesh</td>
<td>Form: composition</td>
<td>wood, plastic, fiberglass</td>
</tr>
<tr>
<td>Stays in the water during swimming</td>
<td>Form: position and motion</td>
<td>Is moved in and out of the water</td>
</tr>
<tr>
<td>Alligator flesh heals naturally</td>
<td>Repair</td>
<td>May be glued or taped</td>
</tr>
<tr>
<td>Weighs many pounds</td>
<td>Form: weight</td>
<td>Lightweight</td>
</tr>
</tbody>
</table>
Figure 9. Example Front (on the left) and Back of a Card (on the right) for Beaver Set

Hand Saw

A hand saw has large, sharp teeth to cut and tear through wood by a back and forth motion. Similarly, a beaver gnaws at a tree taking layer after layer of it off until the beaver cuts all the way through.

Table 8. Mapping One of the Analogies for Beaver

<table>
<thead>
<tr>
<th>Similarities = Mapping the Analogy</th>
<th>Category</th>
<th>Hand Saw</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beaver Teeth</strong></td>
<td><strong>Category</strong></td>
<td><strong>Hand Saw</strong></td>
</tr>
<tr>
<td>Sharp, chisel-shaped teeth</td>
<td>Form: angularity</td>
<td>Sharp teeth along saw blade</td>
</tr>
<tr>
<td>Strong, hard material</td>
<td>Form: strength</td>
<td>Strong, hard material</td>
</tr>
<tr>
<td>Several teeth used</td>
<td>Form: number</td>
<td>Several teeth used</td>
</tr>
<tr>
<td>Cut wood</td>
<td>Function</td>
<td>Cut wood</td>
</tr>
<tr>
<td>Produces chips and sawdust</td>
<td>Form: products</td>
<td>Produces chips and sawdust</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Differences = Limits of the Analogy</th>
<th>Category</th>
<th>Hand Saw</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beaver Teeth</strong></td>
<td><strong>Category</strong></td>
<td><strong>Hand Saw</strong></td>
</tr>
<tr>
<td>Orange- have natural iron oxide coating that strengthens teeth</td>
<td>Form: color</td>
<td>Silvery saw blade</td>
</tr>
<tr>
<td>Enamel</td>
<td>Form: composition</td>
<td>Steel</td>
</tr>
<tr>
<td>Prying, chipping motion</td>
<td>Form: motion</td>
<td>Back and forth saw motion</td>
</tr>
<tr>
<td>Teeth constantly growing</td>
<td>Repair</td>
<td>Blade can be sharpened or replaced</td>
</tr>
<tr>
<td>Grow naturally in beaver’s mouth</td>
<td>Origin</td>
<td>Purchased at hardware store</td>
</tr>
</tbody>
</table>
Figure 10. Example Front (left) and Back of a Card (right) from the Bluebird Set

The bluebird’s feathers are oiled to repel water so that birds can fly when it’s raining.

Raincoat
A raincoat is made of waterproof fabric to repel water so that the wearer can go out in rainy weather and stay dry. Similarly, the bluebird feathers repel water to help the bird stay dry when it is raining.

Table 9. Mapping One of the Analogies for Bluebird

<table>
<thead>
<tr>
<th>Similarities = Mapping the Analogy</th>
<th>Category</th>
<th>Raincoat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluebird Feathers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bright blue and red colors</td>
<td>Form: color</td>
<td>May be bright colors</td>
</tr>
<tr>
<td>Feathers insulate the bird’s body</td>
<td>Form: insulating</td>
<td>Fibers are woven and insulate the wearer</td>
</tr>
<tr>
<td>Oily coating repels water</td>
<td>Form: water repellant</td>
<td>Slick surface repels water</td>
</tr>
<tr>
<td>Protect bird from inclement weather</td>
<td>Function</td>
<td>Protect wearer from inclement weather</td>
</tr>
<tr>
<td>Feathers cover body shape</td>
<td>Form: fits body shape</td>
<td>Cloth fits body shape</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Differences = Limits of the Analogy</th>
<th>Category</th>
<th>Raincoat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluebird Feathers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Always blue and sometimes other colors</td>
<td>Form: color</td>
<td>May be any color</td>
</tr>
<tr>
<td>Feathers</td>
<td>Form: composition</td>
<td>Fabric or plastic</td>
</tr>
<tr>
<td>Individual feathers can be ruffled</td>
<td>Form: surface texture</td>
<td>Smooth surfaces</td>
</tr>
<tr>
<td>Bird grows more feathers</td>
<td>Repair</td>
<td>Holes can be patched</td>
</tr>
<tr>
<td>Feathers are molted but never completely</td>
<td>Form: removability</td>
<td>Can be completely removed from body</td>
</tr>
</tbody>
</table>
Invention through Form and Function Analogy by Audrey C. Rule

Figure 11. Example Front (left) and Back of a Card (right) from the Owl Set

Owls have very sharp and well-focused eyesight that helps owls see their prey in the dark.

Binoculars

The binoculars make images of things far away sharper and better focused so that they are easier to see. Similarly, the eyesight of an owl is sharp to help them see their prey better at night.

Table 10. Mapping One of the Analogies for Owl

<table>
<thead>
<tr>
<th>Similarities = Mapping the Analogy</th>
<th>Category</th>
<th>Binoculars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owl Eyes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both eyes see same object</td>
<td>Form: binocular vision</td>
<td>Both eyes see same object for depth perception</td>
</tr>
<tr>
<td>for depth perception</td>
<td>Form: able to focus</td>
<td>Dial allows viewer to focus binoculars</td>
</tr>
<tr>
<td>Muscles in eyes allow eyes to</td>
<td>Form: able to see distant objects</td>
<td>Lenses allow viewer to see at distance</td>
</tr>
<tr>
<td>focus</td>
<td>Function</td>
<td>Watch small animals</td>
</tr>
<tr>
<td>Keen eyesight for distances</td>
<td>Form: two “eyes”</td>
<td>Two lenses</td>
</tr>
<tr>
<td>Watch small animals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two eyes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Differences = Limits of the Analogy</th>
<th>Category</th>
<th>Binoculars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owl Eyes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colored iris is often yellow</td>
<td>Form: color</td>
<td>Housing of binoculars is often black</td>
</tr>
<tr>
<td>Made of living tissue</td>
<td>Form: composition</td>
<td>Made of plastic and glass</td>
</tr>
<tr>
<td>Part of bird ‘s body</td>
<td>Form: origin</td>
<td>Manufactured tool</td>
</tr>
<tr>
<td>Hunting prey for survival</td>
<td>Function</td>
<td>Watching birds and animals for enjoyment</td>
</tr>
<tr>
<td>Not able to remove</td>
<td>Form: removability</td>
<td>Can be stored in car or closet</td>
</tr>
</tbody>
</table>
**Figure 12. Example Front (left) and Back of a Card (right) from the Whale Set**

![Image of a whale and a card]

**Bicycle Training Wheels**

Training wheels on a bicycle help a child balance the bike. The wheels distribute some of the weight farther from the central axis and provide extra surfaces for balancing the bike on the road. Similarly, a whale has side fins to stabilize it in the water.

**Table 11. Mapping One of the Analogies for Whale**

<table>
<thead>
<tr>
<th>Similarities = Mapping the Analogy</th>
<th>Category</th>
<th>Bicycle Training Wheels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whale Side Fins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symmetrical placement of fins</td>
<td>Form: symmetry</td>
<td>Symmetrical placement of training wheels</td>
</tr>
<tr>
<td>Balancing and stability</td>
<td>Function</td>
<td>Balancing and stability</td>
</tr>
<tr>
<td>Two fins</td>
<td>Form: number</td>
<td>Two wheels</td>
</tr>
<tr>
<td>Near bottom of whale</td>
<td>Form: placement</td>
<td>Near bottom of bike</td>
</tr>
<tr>
<td>Push against water</td>
<td>Function: pushing</td>
<td>Push against road surface</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Differences = Limits of the Analogy</th>
<th>Category</th>
<th>Bicycle Training Wheels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whale Side Fins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living tissue</td>
<td>Composition</td>
<td>Metal and rubber</td>
</tr>
<tr>
<td>Paddling</td>
<td>Motion</td>
<td>Rolling</td>
</tr>
<tr>
<td>Near front of whale</td>
<td>Form: Placement</td>
<td>Near rear of bike</td>
</tr>
<tr>
<td>Natural part of whale</td>
<td>Origin</td>
<td>Manufactured item</td>
</tr>
<tr>
<td>For whales throughout life</td>
<td>Function</td>
<td>For novice bike riders</td>
</tr>
</tbody>
</table>
Invention through Form and Function Analogy by Audrey C. Rule

Figure 13. Example Front (left) and Back of a Card (right) from the Wolf Set

A wolf’s undercoat is thick, soft, and dense. The undercoat protects a wolf’s skin from extreme heat and cold.

Potholder
A potholder is thick, soft, and dense. It is designed to protect a person’s hand from extreme heat. Similarly, the thick, soft, and dense undercoat of a wolf protects the wolf’s skin.

Table 12. Mapping One of the Analogies for Wolf

<table>
<thead>
<tr>
<th>Similarities = Mapping the Analogy</th>
<th>Category</th>
<th>Potholder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolf’s Undercoat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hair fibers</td>
<td>Form: fibrous nature</td>
<td>Cotton or polyester fibers</td>
</tr>
<tr>
<td>Hair protects wolf from temperature extremes</td>
<td>Function: insulator</td>
<td>Potholder pad protects from temperature extremes</td>
</tr>
<tr>
<td>Less than a couple of inches thick</td>
<td>Form: thickness</td>
<td>Less than a couple of inches thick</td>
</tr>
<tr>
<td>Undercoat is usually white hair</td>
<td>Form: color</td>
<td>Cotton fibers are white</td>
</tr>
<tr>
<td>Protect wolf from temperature extremes</td>
<td>Function: protection</td>
<td>Protect user from temperature extremes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Differences = Limits of the Analogy</th>
<th>Category</th>
<th>Potholder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolf’s Undercoat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mostly for cold weather, but</td>
<td>Function</td>
<td>Mostly protects from heat but can be used for handling cold items</td>
</tr>
<tr>
<td>insulates from heat somewhat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Covers most of body-irregular shape</td>
<td>Form: shape</td>
<td>Usually square</td>
</tr>
<tr>
<td>Wolf hair</td>
<td>Composition</td>
<td>Cotton or synthetic fibers</td>
</tr>
<tr>
<td>Wolf licks clean</td>
<td>Cleaning</td>
<td>Put in washing machine</td>
</tr>
<tr>
<td>Wolf grows more hair</td>
<td>Repair</td>
<td>Patch or replace with a new one</td>
</tr>
</tbody>
</table>
Lesson 7 Activity 3. Ask students to choose one of the form and function analogy cards. Try to generate five other items that could be used as an analogy instead of the suggested object. Tell advantages and disadvantages of using each proposed item. See examples in Table 13 through Table 18.

Figure 14. Example Card with Soda Can Opener used as Analogy for Alligator Teeth

Soda Can Opener
A can opener is sharp for gripping and puncturing the can. Similarly, an alligator has sharp teeth for gripping prey and puncturing the prey to be swallowed easily.

Alligators have sharp canine teeth for puncturing and gripping food.

Table 13. Other Objects that Could Be Used as Analogies for Sharp Alligator Canine Teeth

<table>
<thead>
<tr>
<th>Other Analogous Object</th>
<th>Advantages and Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chipped stone spear head</td>
<td>Sharp and shaped in a similar way, but no jaw action</td>
</tr>
<tr>
<td>Steel pocket knife</td>
<td>Very sharp but no jaw action</td>
</tr>
<tr>
<td>Steel trap</td>
<td>Sharp teeth and jaw snaps shut</td>
</tr>
<tr>
<td>Paper punch</td>
<td>Sharp edge of punch die and jaw action, but “tooth” is cylindrical</td>
</tr>
<tr>
<td>Stapler</td>
<td>Sharp and has jaw action, but leaves tooth in victim</td>
</tr>
</tbody>
</table>

Figure 15. Example Card with Shovel Being Used as an Analogy for Webbed Beaver Feet

Shovel
A shovel is a tool with a broad surface used to scoop up earth. Similarly, beavers’ feet are webbed to produce a broad surface. They are used like a shovel to scoop mud and place it on the beavers’ shelters.

Beavers have webbed feet with broad surfaces to scoop up mud to put on their shelters.
Table 14. Other objects that Could Be Used as Analogies for Webbed Beaver Feet with Broad Surfaces for Scooping Mud

<table>
<thead>
<tr>
<th>Other Analogous Object</th>
<th>Advantages and Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement trowel</td>
<td>Closer in size to beaver feet and can scoop mud</td>
</tr>
<tr>
<td>Spoon</td>
<td>Similar in size to beaver feet but lacking claws</td>
</tr>
<tr>
<td>Dustpan</td>
<td>Larger than beaver feet, but able to scoop mud; no claws</td>
</tr>
<tr>
<td>Ice cream scoop</td>
<td>Cup-shaped and so simulate beaver’s ability to hold mud; no claws</td>
</tr>
<tr>
<td>Fork</td>
<td>Has sharp “claws”; a large fork can scoop a lot of mud</td>
</tr>
</tbody>
</table>

Figure 16. Example Card with an Aluminum Tube Bicycle Frame Being Used as an Analogy for Bird Bones

A bluebird’s skeleton is made of lightweight, hollow bones that support the body, without contributing excess weight.

Bicycle Frame

Bicycle frames are made of lightweight, hollow cylinders that provide the support without adding much weight. This allows riders to travel more efficiently and quickly than walking. Similarly, bluebird skeletons have lightweight, hollow bones that provide the support necessary for flight.

Table 15. Other Objects that Could Be Used as Analogies for Lightweight Hollow Bird Bones

<table>
<thead>
<tr>
<th>Other Analogous Object</th>
<th>Advantages and Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrugated cardboard</td>
<td>This has “tube-shaped” empty spaces on the inside; cardboard is lightweight and used in shipping containers because of its strength</td>
</tr>
<tr>
<td>Bamboo scaffolding</td>
<td>This is another natural material that is rigid and lightweight</td>
</tr>
<tr>
<td>Hollow plastic tent poles</td>
<td>These are lightweight, yet strong and good for backpacking</td>
</tr>
<tr>
<td>Aluminum frame for lawn chairs</td>
<td>These are strong and lightweight for carrying to the beach</td>
</tr>
<tr>
<td>Golf club shaft</td>
<td>These are hollow and made to be lightweight</td>
</tr>
</tbody>
</table>
Figure 17. Example Card with an Oscillating Fan being used as an Analogy for an Owl’s Swiveling Neck Joint

The neck joint allows the owl’s head to rotate as much as 270 degrees. This enables owls to watch a moving object in all directions without moving the whole body.

Oscillating Fan
An oscillating fan has a swivel joint that allows the fan to rotate about 270 degrees to blow air in all directions of a room. Similarly, an owl is able to move its neck 270 degrees to search all areas.

Table 16. Other Objects that Could Be Used as Analogies for an Owl’s Swiveling Neck Joint that Gives it a Greater Range of Visual Operation

<table>
<thead>
<tr>
<th>Other Analogous Object</th>
<th>Advantages and Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lazy Susan turntable</td>
<td>This item can swivel to any angle and has a range of serving anyone around the perimeter.</td>
</tr>
<tr>
<td>Playground roundabout</td>
<td>This equipment can swivel to any angle and allows riders to view the entire playground.</td>
</tr>
<tr>
<td>Gooseneck lamp</td>
<td>This lamp can be twisted to a large range of angles and can “see” or throw light on a variety of objects.</td>
</tr>
<tr>
<td>Gun turrets on battleships</td>
<td>These can turn about 270 degrees to “see” and hit targets.</td>
</tr>
<tr>
<td>Periscope</td>
<td>This can turn to different angles for a wide range of vision</td>
</tr>
</tbody>
</table>

Figure 18. Example Card with a Cage Being Used as an Analogy for Baleen which Allows Liquid to Escape, but Holds Food Trapped

A whale holds food in its mouth until it can be swallowed. The baleen prevents food from escaping.

Cage
A cage has bars that prevent small animals from escaping. Similarly, a whale’s baleen holds food in the mouth until it can be swallowed.
Table 17. Other Objects that Could Be Used as Analogies for Whale Baleen that Holds Food Trapped but Allows Liquid to Escape

<table>
<thead>
<tr>
<th>Other Analogous Object</th>
<th>Advantages and Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee filter</td>
<td>The best part in this case, though, is the coffee liquid, rather than the coffee grounds</td>
</tr>
<tr>
<td>Food strainer</td>
<td>The strainer retains foods like berries that are being washed</td>
</tr>
<tr>
<td>Window screen</td>
<td>Allows air to flow through while keeping insects out (sort of opposite of baleen)</td>
</tr>
<tr>
<td>Playpen</td>
<td>Has bars or netting to keep baby in – but baby is not “food”</td>
</tr>
<tr>
<td>Fishnet</td>
<td>Catches and hold fish and lets water drip out</td>
</tr>
</tbody>
</table>

Figure 19. Example Card with a Police “Do Not Cross this line” Ribbon Being Used as an Analogy for a Wolf’s Tail that can be Positioned to Communicate to Others

Table 18. Other Objects that could be Used as Analogies for a Wolf’s Tail that can be Positioned in Different Ways to Communicate Messages

<table>
<thead>
<tr>
<th>Other Analogous Object</th>
<th>Advantages and Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semaphore flags</td>
<td>These flags are held in different positions to signal different messages.</td>
</tr>
<tr>
<td>Arrows on signs</td>
<td>Arrows can be positioned to indicate different messages</td>
</tr>
<tr>
<td>Railroad barrier signals</td>
<td>These barriers move up and down to signal whether one can cross the tracks.</td>
</tr>
<tr>
<td>Sign language</td>
<td>People position their hands in different ways to send different messages</td>
</tr>
<tr>
<td>Secret spy messages</td>
<td>Spies have secret ways of positioning objects to communicate messages such as raising or lowering window shades</td>
</tr>
</tbody>
</table>
Lesson 8

Invention through Form and Function Analogy

Objectives: Students will be able to match an inventor’s interest, inspiration, the form and function of the invention, and the new product. Students will be able to discuss how form and function analogies helped many inventors develop new products. Students will be able to research an inventor of interest and make a poster that communicates information to other class members.

Exploration: Ask students to name a product that was inspired by an analogy to the form and function of something else.

Explanation: Pass out a set of the Lesson 8 cards to each small group of students. Their job is to create a large chart with the cards. Each row should focus on the invention of one inventor. Place the inventors to form the first column. The next column should show the corresponding inspirational idea. Column 3 should show the form and function. The last column should show the new invention. After students have completed the charts, discuss the inventions and how form and function was used to help the inventors.

Figure 20. Card Set 7, Form and Function Inspirational Ideas for New Products

<table>
<thead>
<tr>
<th>Inspirational Idea</th>
<th>Form and Function</th>
<th>Inventor</th>
<th>New Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>A waffle iron produces a pattern of squares as the batter cools.</td>
<td>A liquid fills squares holes in a mold to produce a square pattern.</td>
<td>Oregon Coach Bill Bowerman who wanted his track athletes to perform better. He co-founded Nike.</td>
<td>Rubber was poured into a mold to make a waffle-sold shoe. This sole allowed athletes better traction and cushioning.</td>
</tr>
<tr>
<td>Thinking about how many things in nature are spherical, including the Earth.</td>
<td>Position the surface of a sphere all equally distant from the center.</td>
<td>Dr. Philip Emeagwali, born in Nigeria, now living in the United States. He is interested in super computers.</td>
<td>Hyperball computer with numerous processing nodes that are spherically connected to calculate global warming effects.</td>
</tr>
</tbody>
</table>
Figure 20 (Continued). Card Set 7, Form and Function Inspirational Ideas for New Products

<table>
<thead>
<tr>
<th>Inspirational Idea</th>
<th>Form and Function</th>
<th>Inventor</th>
<th>New Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Images and letters on coins were made by passing a die (metal stamp) into the metal. Could this idea be applied to making letters on paper?</td>
<td>The shape of a die (metal stamp) is produced on a flat surface by stamping.</td>
<td>German printer Johannes Gutenberg was interested in printing paper and books more quickly.</td>
<td>The printing press had metal letters that could be arranged to form words. These were inked and pressed onto the paper to make many copies.</td>
</tr>
<tr>
<td>People in small apartments in New York City need compact furniture to make the best use of the space.</td>
<td>Hinges in the furniture allow a bed to be folded into a writing desk to make the best use of limited space.</td>
<td>Sarah E. Goode was a former slave and the first African-American woman to hold a U.S. patent.</td>
<td>Folding Cabinet Bed, U.S. Patent Number 322,177, issued July 14, 1865</td>
</tr>
<tr>
<td>As steam builds inside the pot, the lid vibrates with the pressure.</td>
<td>Steam produced by hot liquid takes up more space and produces pressure.</td>
<td>Scottish Mechanical Engineer James Watt was fascinated with steam.</td>
<td>Steam engines were powered by steam pressure.</td>
</tr>
<tr>
<td>A customer complained that the French fries were too thick. As a joke, Chef Crum cut the potatoes so thin they could not be eaten with a fork.</td>
<td>The thin, crispy potato chip crunched in a pleasing manner. Customers loved them.</td>
<td>George Crum was a Native American/African American chef at a restaurant in Saratoga Springs, NY in 1853.</td>
<td>Potato chips were thin and crispy to delight customers with a new snack.</td>
</tr>
<tr>
<td>A coiled hose of a flexible garden reminded the inventor of a wheel.</td>
<td>A long fluid-filled cylinder made of flexible material can be bent into a circle and used to cushion impacts.</td>
<td>Scottish Inventor John Dunlop with a young son who liked to ride a tricycle.</td>
<td>The first air-filled tire was made for the inventor’s son’s tricycle. The inventor wound an airtight piece of a garden hose around the wheel and covered it with a rubber tread. The tire now absorbed shocks.</td>
</tr>
<tr>
<td>Soaring birds have thin wings to retain balance while flying.</td>
<td>Curved surfaces deflect air giving lift and stability to vehicles.</td>
<td>The Wright Brothers wanted to build and fly planes.</td>
<td>Wounded wings on aircraft for lift and stability.</td>
</tr>
</tbody>
</table>
### Figure 20 (Continued). Card Set 7, Form and Function Inspirational Ideas for New Products

<table>
<thead>
<tr>
<th>Inspirational Idea</th>
<th>Form and Function</th>
<th>Inventor</th>
<th>New Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>A cat (shaking its tail) through a rope (many times, and every time it hits the rope) through the rope sparked an idea of separating cotton seeds from cotton fibers.</td>
<td><strong>Form and Function</strong></td>
<td><strong>Inventor</strong></td>
<td><strong>New Product</strong></td>
</tr>
<tr>
<td>Flexible cotton fibers are pulled through a grating or a comb.</td>
<td><strong>Inventor</strong></td>
<td>Former American farmer, Eli Whitney, who wanted to improve agriculture.</td>
<td>The cotton gin separated cotton fibers from the seeds that were tightly attached. The comb reached through a grating to pull out the cotton fibers, leaving the seeds.</td>
</tr>
<tr>
<td>A telescoping shower head adjusts to different heights and distances from the showering person.</td>
<td><strong>Form and Function</strong></td>
<td>NASA Engineer, James Crocker, who wanted to fix the Hubble Space telescope by putting an adjustable lens.</td>
<td>Automated arms that could be aligned were used to position the mirrors at the exact distance needed to repair the Hubble Space Telescope.</td>
</tr>
<tr>
<td>Wet leaves are stacked and packed in a rain gutter without broke or damaged, but all of them bent into a curved shape.</td>
<td><strong>Form and Function</strong></td>
<td>Federico Baur, an American chemist and food storage technician.</td>
<td>Pringles chips have a saddle shape that allows them to stack.</td>
</tr>
<tr>
<td>Cattleburs have hooks that stick to dog’s fur.</td>
<td><strong>Form and Function</strong></td>
<td>Swiss Engineer, George de Mestral, who liked to walk the fields with haying.</td>
<td>Velcro fasteners are made of a looped fiber tape and a tape covered in hooks that stick together.</td>
</tr>
</tbody>
</table>

**Expansion:** Students should read about an inventor and his/her work. Each student should make a presentation to the rest of the class, perhaps making a poster of information about the inventor. Student posters should include the following:

- A picture of the inventor
- A picture of the product
- A description of the inventor’s background
- A description of how the inventor obtained creative ideas
- Forms and function of the product (including how it works)
- Five other interesting facts about the inventor or invention
Lesson 9. Use SCAMPER method combined with form and function analogies to make product innovations or inventions.

Lesson 9 Activity 1.

Objective: Students will be able to apply the forms and functions of animal body parts to products to produce innovations.

Use an empty SCAMPER chart similar to the one in Table 19. Note that the word SCAMPER is an acronym for the key words Substitute, Combine, Adapt, Modify-Minify-Maximize, Put to another use, Eliminate, and Reverse-rearrange-reorder. First, have students recall adaptations from one of the animals studied through form and function. Write these ideas in the middle column of the chart. At first, place them on any line, with the idea that their positions might be changed later. After the middle column has been filled, begin playing with these ideas to produce product innovations. For example, start with the first SCAMPER idea, “Substitute.” Ask students how the animal adaptation might lead to some sort of substitution (in an aspect) regarding the product. Perhaps it is a substitution of materials, or a new part for an old part, or a substituted use of the product. Write the resulting ideas in the last column. Then proceed to the next line and explore those ideas. Sometimes, one can see that the animal adaptation fits better with a different SCAMPER idea. In that case, move the animal adaptations to different lines of the chart. More than one idea may be written on the chart for each line. Example charts for different animals and different products follow as Tables 20 to 25.
### Table 19. Blank Scamper Chart

<table>
<thead>
<tr>
<th>Scamper Operation</th>
<th>Animal Adaptation Idea</th>
<th>Applying idea to improve:______________</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Substitute</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Combine</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>Adapt</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>Modify, Minify, Maximize</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>Put to another use</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Eliminate</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>Reverse, reorganize</td>
<td></td>
</tr>
</tbody>
</table>
Table 20. Example Scamper Chart Related to “Alligator” Used to Improve a Chair

<table>
<thead>
<tr>
<th>Scamper Operation</th>
<th>Animal Adaptation Idea</th>
<th>Applying idea to improve a chair</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Substitute Alligators have movable flaps on their ears that close to prevent water intrusion</td>
<td>The chair might have a seat cushion and back cushion that are inflated to different amounts of cushioning and firmness rather than cushions stuffed with foam or batting or no cushion</td>
</tr>
<tr>
<td>C</td>
<td>Combine An alligator bellows or growls to communicate with others</td>
<td>Combine the chair with a silent electronic communication system so that a waiter or servant or friend can receive a message and bring the sitter a drink or snack</td>
</tr>
<tr>
<td>A</td>
<td>Adapt Alligators have a tan-green body covering that is camouflaged in the environment</td>
<td>Change the chair fabric so that it is paintable so it can be spray-painted to match its surroundings and blend in. This might be nice for garden parties with lots of guests. This way, the chairs won’t detract from the flower garden but blend in</td>
</tr>
<tr>
<td>M</td>
<td>Modify, Minify, Maximize Put to another use An alligator has strong jaws that snap shut to hold onto things</td>
<td>Modify the back of the chair so that it has a giant clip that holds reading material out of sight</td>
</tr>
<tr>
<td>P</td>
<td>Put to another use An alligators have wide nostrils on their snouts so they can breathe while submerged</td>
<td>Instead of a typical indoor house furnishing chair, make the chair be for the bottom of a 3 to 4 foot deep pool so that a person can stay submerged to cool off and avoid sunburn; there would be a snorkel mask attached so that the person can breathe while relaxing under the water</td>
</tr>
<tr>
<td>E</td>
<td>Eliminate An alligator has a glottis flap in its throat that opens to allow food through</td>
<td>Eliminate the idea of a permanent back to the chair; allow the back to flip to different positions</td>
</tr>
<tr>
<td>R</td>
<td>Reverse, reorganize Alligators have smooth skin on their bellies</td>
<td>Substitute smooth plastic for all the areas of the chair so that it can potentially be flipped over and sat in three different ways with their being a continuous sculpture rather than a chair with legs</td>
</tr>
</tbody>
</table>
**Table 21. Example Scamper Chart Related to “Beaver” Used to Improve a Pair of Gloves.**

<table>
<thead>
<tr>
<th>Scamper Operation</th>
<th>Animal Adaptation Idea</th>
<th>Applying idea to improve a pair of gloves</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S</strong> Substitute</td>
<td>Beavers cover their lodge floors with wood chips to absorb water and keep the floor from being muddy</td>
<td>Substitute tough, woody, sisal fibers for the outer coating of the gloves to make them tough and to protect the hands</td>
</tr>
<tr>
<td><strong>C</strong> Combine</td>
<td>Beaver lodges are surrounded by water for protection</td>
<td>Put an absorbent liner inside the gloves and squirt lotion on it to surround the hands with healing liquid that protects the skin</td>
</tr>
<tr>
<td><strong>A</strong> Adapt</td>
<td>Beavers have large flat tails for slapping the water to indicate danger</td>
<td>Put flat metal plates into the palms so that people can make more noise when clapping at a performance; call these “opera gloves”</td>
</tr>
<tr>
<td><strong>M</strong> Modify, Minify, Maximize</td>
<td>Beaver lodges are covered with a thick layer of mud and twigs for insulation</td>
<td>Make the gloves insulated; have some gloves with twig-like supports in the fingers to support the fingers when carrying loads in the hands</td>
</tr>
<tr>
<td><strong>P</strong> Put to another use</td>
<td>Beavers have webbed feet to push against the water or pick up and pack mud</td>
<td>Make the fingers of the glove webbed. Use these gloves for playing volleyball or other ball sports in which more hand contact with the ball is desired</td>
</tr>
<tr>
<td><strong>E</strong> Eliminate</td>
<td>Beavers have two underwater passages for accessing their lodges</td>
<td>Have gloves with a wrist entrance and another hole cut in the palm near the roots of the fingers; the gloves can be worn over the palm with the fingers free if needed</td>
</tr>
<tr>
<td><strong>R</strong> Reverse, reorganize</td>
<td>Beaver teeth never stop growing</td>
<td>Put some pleats in the gloves so that they will fit a variety of hand sizes</td>
</tr>
</tbody>
</table>
### Table 22. Example Scamper Chart Related to “Bluebird” Used to Improve a Hair Style

<table>
<thead>
<tr>
<th>Scamper Operation</th>
<th>Animal Adaptation Idea</th>
<th>Applying idea to improve a hair style</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S</strong> Substitute</td>
<td>Bluebird beaks are made of two parts that pinch together to hold onto objects</td>
<td>Substitute a variety of clips for rubber bands. Divide the hair into two sections; twist these around each other For a short haircut, divide the hair into two sections; use mousse to make them into two peaks</td>
</tr>
<tr>
<td><strong>C</strong> Combine</td>
<td>Female bluebirds have white rings around the eyes to signify their sex</td>
<td>Combine decorations with the hair by placing white rings around braids or bunches of hair to decorate the hair Add barrettes in the hair that say “Girl” or the person’s name</td>
</tr>
<tr>
<td><strong>A</strong> Adapt</td>
<td>Bluebird wings spread out to form broad, flat surfaces for flight</td>
<td>Gather the hair into a ponytail on top of the head and then use mousse to flatten it out into a draped covering of the head</td>
</tr>
<tr>
<td><strong>M</strong> Modify, Minify, Maximize</td>
<td>A bluebird’s feathers are oiled to repel water</td>
<td>Use oily Vaseline to sculpt a new hair arrangement</td>
</tr>
<tr>
<td><strong>P</strong> Put to another use</td>
<td>Bluebirds have hollow bones for lightweight in flying</td>
<td>Roll the hair on fancy decorated hollow rollers that stay in the hair Make the hair into ringlets that are pulled back by a headband and “fly” around the face</td>
</tr>
<tr>
<td><strong>E</strong> Eliminate</td>
<td>Bluebirds are able to hover to find insects</td>
<td>Eliminate curls and bouncy hair that “hovers” by covering with a netted cap Place beautiful butterfly and other insect pins in the hair for decoration</td>
</tr>
<tr>
<td><strong>R</strong> Reverse, reorganize</td>
<td>A bluebird’s nest is woven together into a cup shape</td>
<td>Start by sectioning the hair into braids and then weave the braids together to form a network Weave ribbons or interesting twigs into the hair</td>
</tr>
</tbody>
</table>
Table 23. Example Scamper Chart Related to “Owl” Used to Improve a Window

<table>
<thead>
<tr>
<th>Scamper Operation</th>
<th>Animal Adaptation Idea</th>
<th>Applying idea to improve a window</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Substitute Owls are active at night</td>
<td>Most people look out the windows during the day; make a special night-gazing window in the ceiling for watching the stars and moon</td>
</tr>
<tr>
<td>C</td>
<td>Combine Owls have ear tufts that are positioned to show moods</td>
<td>Have a series of partial shutters and screens for the window that can be arranged to let in more or less light for different moods</td>
</tr>
<tr>
<td>A</td>
<td>Adapt Owls have sharp-focused eyesight</td>
<td>Have a line of special lenses built into the window so you can look out through them and see a great distance</td>
</tr>
<tr>
<td>M</td>
<td>Modify, Minify, Maximize Owl neck joints rotate as much as 270 degrees</td>
<td>Modify the window frame so that it can swivel to open the window</td>
</tr>
<tr>
<td>P</td>
<td>Put to another use Owls have sharp, curved talons for catching prey</td>
<td>Have a row of sharp clips above the window for attaching a variety of curtains made of flat sheets of fabric that are gathered by the clips. Change these as your mood changes</td>
</tr>
<tr>
<td>E</td>
<td>Eliminate Owls have soft feathers that muffle sounds</td>
<td>Have several screens made of soft baffles that muffle sounds from an open window.</td>
</tr>
<tr>
<td>R</td>
<td>Reverse, reorganize Owls are camouflaged to become unnoticed in their surroundings</td>
<td>Change the window to become the focal point of the room and use bold colors in its framing and curtains to draw attention</td>
</tr>
</tbody>
</table>
Table 24. Example Scamper Chart Related to “Whale” Used to Improve a Rug

<table>
<thead>
<tr>
<th>Scamper Operation</th>
<th>Animal Adaptation Idea</th>
<th>Applying idea to improve a rug</th>
</tr>
</thead>
<tbody>
<tr>
<td>S Substitute</td>
<td>Barnacles often attach to whales</td>
<td>Rugs often acquire stains; substitute a rug fabric dye for the stains; allow people to “paint” their rugs with attractive colors to hide stains</td>
</tr>
<tr>
<td>C Combine</td>
<td>Whales travel in pods for socializing and safety</td>
<td>Have a basic-colored base rug with a lot of highly-decorated smaller rugs on top that are then securely attached</td>
</tr>
<tr>
<td>A Adapt</td>
<td>Whales have long fibrous baleen that sifts food</td>
<td>Have fibrous rugs at the entrance that sift dirt from shoes and empty it into a pan underneath</td>
</tr>
<tr>
<td>M Modify, Minify, Maximize</td>
<td>Whales have side fins that help it balance and remain stable in the water</td>
<td>Have some extensions from the rug that slide behind baseboards to stabilize the rug’s position</td>
</tr>
<tr>
<td>P Put to another use</td>
<td>Whales make whistles, buzzes and cries to communicate</td>
<td>Put a sensor under the rug at the entranceway that makes a sound when someone enters the room to alert others</td>
</tr>
<tr>
<td>E Eliminate</td>
<td>Whales have fat layers for insulation</td>
<td>Eliminate chills from the floor with a highly-insulating rug</td>
</tr>
<tr>
<td>R Reverse, reorganize</td>
<td>Whales have blowholes through which they breathe</td>
<td>Have porous areas of the rug that overlay vents and allow cold air to return to the furnace unnoticed</td>
</tr>
</tbody>
</table>
**Table 25. Example Scamper Chart Related to Wolf Used to Improve a Shoe**

<table>
<thead>
<tr>
<th>Scamper Operation</th>
<th>Animal Adaptation Idea</th>
<th>Applying idea to improve a shoe</th>
</tr>
</thead>
<tbody>
<tr>
<td>S Substitute</td>
<td>A wolf’s nose has a keen sense of smell</td>
<td>Substitute a porous fabric for leather so that the shoe is airy and doesn’t smell bad</td>
</tr>
<tr>
<td>C Combine</td>
<td>Wolves live in groups called packs and work together</td>
<td>Shoes could be sold as packs that include socks and extra shoe laces</td>
</tr>
<tr>
<td>A Adapt</td>
<td>Wolves have long, curved, sharp toenails</td>
<td>Shoes can have an open toe area for someone with nails that stick out so that nails don’t press against the shoe; this area can be screened over to keep out pebbles</td>
</tr>
<tr>
<td>M Modify, Minify, Maximize</td>
<td>A wolf has a thick, soft, dense undercoat to insulate</td>
<td>Pad the sole with a thick spongy layer to cushion impacts and insulate from hot tar surfaces</td>
</tr>
<tr>
<td>P Put to another use</td>
<td>Wolves have cupped ears to gather sound waves</td>
<td>Place GPS units in kids’ shoes so that the travels can be tracked by parents on a computer</td>
</tr>
<tr>
<td>E Eliminate</td>
<td>A wolf has a smooth topcoat to repel rain</td>
<td>Eliminate the need for waterproofing by making the entire shoe submersible and having holes on the sides and in the sole for water drainage</td>
</tr>
<tr>
<td>R Reverse, reorganize</td>
<td>Wolves have sharp incisor teeth to rip and tear</td>
<td>Have repair kits sold with the shoes to stop rips and tears</td>
</tr>
</tbody>
</table>
References


APPENDIX FOR INVENTION THROUGH FORM AND FUNCTION ANALOGY

Dr. Audrey C. Rule
Center for Educational Transformation
Forms and Functions of the Hand with Analogous Manufactured Tools

Preparation: These are one-sided cards that should be cut apart and mixed before being given to the student. The first page shows heading cards that should be used at the top of each column. A small group of students should be given this complete set or half of it. Therefore, depending upon class size, several sets will need to be made.

Directions for Student Work: Students should work in pairs or small groups of no more than four members. Students’ task is to form a chart-like layout with the cards in each row arranged as shown in the sets here. The order of the rows is not important. Students should use the heading cards to form the columns of the layout.
Fingers can bend around the edge of an object in the palm.

keeps object from falling out of palm

Loosely holding a hot dog sandwich

A tray is has raised edges to loosely hold cups in place

Closed fist can be pressed against something

Supporting the weight to steady the object

Relaxing neck muscles while thinking

A pillow to supports the head, allowing rest
Form | Function | Example Action | Example Tool
--- | --- | --- | ---
Hand is planar with flat palm and fingers fanned out | Broad surface for visibility | Waving and signaling | Flag that is waved to signal
Hand is planar with flat palm and fingers held together | Broad surface to produce noise | Clapping to show approval or gain attention | Cymbals to clang together
Two fingers can be raised while others are curled | Symbolizing; sending message | Signifying victory to others | Badge to symbolize ideas
<table>
<thead>
<tr>
<th>Form</th>
<th>Function</th>
<th>Example Action</th>
<th>Example Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand has jointed fingers</td>
<td>Fingers curl around object to hold it</td>
<td>Holding a phone</td>
<td>Straps on backpack</td>
</tr>
<tr>
<td>Fingers have tough, sharp</td>
<td>Scratch a surface with nails</td>
<td>Scratching someone’s back</td>
<td>Scrub brush for scratching off dirt</td>
</tr>
<tr>
<td>Thump can move to meet</td>
<td>Pincer grip for grasping objects</td>
<td>Holding a pen</td>
<td>Binder clip grips papers</td>
</tr>
<tr>
<td>Form</td>
<td>Function</td>
<td>Example Action</td>
<td>Example Tool</td>
</tr>
<tr>
<td>------</td>
<td>----------</td>
<td>----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Index finger can be extended while other fingers are curled</td>
<td>Small surface area for <strong>touching objects</strong></td>
<td>Pressing a mouse button</td>
<td>Stylus for touching items on a computer screen</td>
</tr>
<tr>
<td>Index finger can be extended while other fingers are curled</td>
<td><strong>Draw attention</strong> to a small area; point or gesture</td>
<td>Pointing to an item of interest</td>
<td>Laser Pointer for presentations</td>
</tr>
<tr>
<td>Palm, fingers and thumb can form cup-shape</td>
<td><strong>Holding</strong> liquids, loose items, cradling object</td>
<td>Holding water</td>
<td><strong>Cup</strong> for holding pencils and other items</td>
</tr>
</tbody>
</table>
**Form**
- Hand has joints and strong muscles

**Function**
- Exert pressure to shape an object

**Example Action**
- Shaping pottery bowl

**Example Tool**
- Rolling pin to shape dough

---

**Form**
- Fingers have flat, glossy nails at tips of fingers

**Function**
- Draw attention to hands

**Example Action**
- Polishing or painting fingernails for attention to beauty

**Example Tool**
- Shiny, rings gain attention as they shimmer

---

**Form**
- Fist can be clenched into a ball

**Function**
- Solid, hard object can strike a strong blow

**Example Action**
- Striking a ball in a volleyball game

**Example Tool**
- Wrecking ball knocks down buildings
Early Artifacts and Tools as Extensions of *Forms* and *Functions* of the Human Body

**Preparation:** These are one-sided cards that should be cut apart and mixed before being given to the student. The first page shows heading cards that should be used at the top of each column. A small group of students should be given this complete set or half of it. Therefore, depending upon class size, several sets will need to be made. Providing real examples of the tools that can be matched to each row of the chart will make the work easier to understand and more engaging.

**Directions for Student Work:** Students should work in pairs or small groups of no more than four members. Students’ task is to form a chart-like layout with the cards in each row arranged as shown in the sets here. The order of the rows is not important. Students should use the heading cards to form the columns of the layout.
<table>
<thead>
<tr>
<th>Artifact and Form</th>
<th>Function of the Tool</th>
<th>Human Body Part Extended</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Artifact and Form</strong></td>
<td><strong>Function of the Tool</strong></td>
<td><strong>Human Body Part Extended</strong></td>
</tr>
<tr>
<td>A drum has a broad top surface that resonates and makes a loud sound when slapped.</td>
<td>This tool is used to make percussion rhythms and music.</td>
<td>Slapping one’s thighs with flattened palms to make a rhythmic noise.</td>
</tr>
<tr>
<td>Blowing into a hollow reed flute causes the reed to vibrate.</td>
<td>This tool has holes at different positions along the length that produce different pitches of sound as it is played.</td>
<td>Blowing through mouth and vibrating the lips to produce whistles.</td>
</tr>
</tbody>
</table>
Artifact and Form

A heavy stone **axe head** is **block-shaped** with a **sharp tapered edge** and a **groove** around all or most of the block.

**Function of the Tool**

The heavy weight of the stone and sharp edge allow it to be used to *chop objects such as wood or to be used as a weapon*. The groove allows it to be attached to a handle.

**Human Body Part Extended**

Fists (for pounding); teeth (cutting and breaking apart).

Artifact and Form

A stone **knife** has a fairly **flat top and bottom surface**, but a **sharp serrated edge** all around.

**Function of the Tool**

The sharp edge all around this tool and its fairly large palm-size allow it to be **held in the hand and used for cutting** plants, hides, meat, and other items.

**Human Body Part Extended**

Teeth cutting into something to break off a part.

Artifact and Form

A stone **scraper** has **broad sharp edges**.

**Function of the Tool**

The broad sharp edge is perfect for dragging across a hide to **scrape off** the layer of fat and for **scraping** dirt or skins from carrots or potatoes.

**Human Body Part Extended**

Fingernails (for scratching and scraping); teeth (scraping).
Artifact and Form
An arrowhead is triangular in shape with a point at the tip and sharp edges. Arrowheads often have notches at the base.

Function of the Tool
The pointy end and sharp edges make it penetrate an animal's or enemy's body to injure or kill it. The notches allow the tool to be attached to a shaft.

Human Body Part Extended
Fists (for punching); teeth for cutting.

Artifact and Form
A strong stone hoe has a large, flat tapering wedge-shaped rectangular shape with sharp edges.

Function of the Tool
The strong wedge can be pushed into the ground to dig a hole for planting or remove weeds.

Human Body Part Extended
Hands (for pushing into the ground).

Artifact and Form
A leather or woven pouch or bag is lightweight flexible, and made of readily-available materials. It can expand to hold more items.

Function of the Tool
This tool functions as a container to hold items. It can expand or contract a bit to hold more or less.

Human Body Part Extended
Hands (holding items).
Artifact and Form

An basket is made of strips of wood or plant stems woven together. It is lightweight and hollow. It may have a lid or cover.

Function of the Tool

The hollow nature of this item allows it to hold or contain items like seeds, berries, and other foods or personal items.

Human Body Part Extended

Hands (holding items).

Artifact and Form

A blanket is a broad flat layer made of soft skins or woven fabric. It is flexible and can be wrapped or arranged in many shapes.

Function of the Tool

The fibrous layer is used to trap body heat or to insulate/protect a person from dampness or cold.

Human Body Part Extended

Like having a thicker skin or more hair.

Artifact and Form

A stone drill is a fairly small tool with a long, sharp pointed end.

Function of the Tool

This tool is turned or twisted on a surface to bore a hole in that surface.

Human Body Part Extended

Fingernails scratching a hole in something.
Artifact and Form
A visor or hat with a brim is made of woven basketry, leather, or fabric. It extends above the forehead.

Function of the Tool
This lightweight item extends out from the head to shade or shelter the eyes from sun and rain.

Human Body Part Extended
Hand shading the face.

Artifact and Form
A strand of beads is a colorful, attractive set of small items that are held together by string or a leather thong.

Function of the Tool
The colorful items attract attention, are considered beautiful or a symbol of wealth and status.

Human Body Part Extended
Colorful, shiny, and interesting like eyes, lips, and teeth.

Artifact and Form
A pair of sandals is woven of grasses or leather with a tough bottom.

Function of the Tool
This item protects the soles of the feet from injury.

Human Body Part Extended
Skin - a layer of hard, tough skin on the bottom of feet.
Card Set # 3

Early and Modern Inventions in Response to Basic Human Needs

**Preparation:** These are one-sided cards that should be cut apart and mixed before being given to the student. The first page shows heading cards that should be used at the top of each column. A small group of students should be given this complete set or half of it. Therefore, depending upon class size, several sets will need to be made.

**Directions for Student Work:** Students should work in pairs or small groups of no more than four members. Students’ task is to form a chart-like layout with the cards in each row arranged as shown in the sets here. The order of the rows is not important. Students should use the heading cards to form the columns of the layout.
**Basic Human Need**

**Communication**: Instruments that produce loud musical tones for alerting others

**Early Invention**: Musical instruments made of wood, shell, horn, or metal

**Modern Invention**: Electronically produced sirens

**Safety**: Health procedures for helping a person recover from a broken bone

**Early Invention**: Making a splint to hold the bone in place

**Modern Invention**: X-rays to examine the bone; medical doctors to set it
<table>
<thead>
<tr>
<th>Basic Human Need</th>
<th>Early Invention</th>
<th>Modern Invention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Food</strong>: Hollow containers for gathering and storing seeds or food materials</td>
<td>Baskets, hollow gourds, pottery bowls</td>
<td>Plastic, glass and ceramic containers / dishes</td>
</tr>
<tr>
<td><strong>Food</strong>: Tools with grinding or cutting surfaces for processing grains, seeds, foods</td>
<td>Mano and metate (grinding stones); mortar &amp; pestle</td>
<td>Blender, food processor</td>
</tr>
<tr>
<td><strong>Food</strong>: Hot heat sources for cooking food</td>
<td>Open camp fire; heated stones</td>
<td>Stove, toaster, microwave oven</td>
</tr>
</tbody>
</table>
### Basic Human Need

**Shelter:**
- Heat source to protect self from cold weather
  - Early Invention: Campfire
  - Modern Invention: Furnace, space heater

**Clothing:**
- Insulating body coverings for warmth or protection from weather
  - Early Invention: Hide or fur blankets, woven cloth clothing/robes
  - Modern Invention: Machine-woven blankets, fitted clothing, synthetic fabrics

**Shelter:**
- Insulating structure to protect from rain and weather extremes
  - Early Invention: Caves and skin, bark, or thatch-covered homes
  - Modern Invention: Insulated brick or frame homes
**Basic Human Need**

**Food:**
Dishes and utensils for serving and eating

**Early Invention**
Spoons, scoops, pottery bowls, gourds, shells

**Modern Invention**
Steel utensils, plastic picnic ware; bowls; fine china

**Basic Human Need**

**Communication:**
Sounds, rhythms and music to communicate mood

**Early Invention**
Rattles from shell, gourds, turtle shells; flutes from hollow bones, reeds

**Modern Invention**
Modern musical instruments; recorded music on CD’s; radio; iPods

**Basic Human Need**

**Communication through Clothing:**
Elaborate, symbolic costumes for ceremonies

**Early Invention**
Costumes with feathers, flowers, shells, wooden decorations

**Modern Invention**
Costumes with glittery fabrics, synthetic beads
Basic Human Need

Safety: Armed humans for protection from animal/enemy attack

Early Invention

Warriors with spears

Modern Invention

Police with guns, army personnel

Basic Human Need

Self Esteem and Communication: Colorful paints applied to the face to communicate mood, status or improve appearance

Early Invention

Paint made of ground hematite or ochre mixed with oil and applied to face

Modern Invention

Modern cosmetics in many colors

Basic Human Need

Communication: Lasting records of events to communicate group history

Early Invention

Petroglyphs, pictographs, drawings on leather, carved records

Modern Invention

Books, ledgers, computer files, films
<table>
<thead>
<tr>
<th>Basic Human Need</th>
<th>Early Invention</th>
<th>Modern Invention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transportation:</strong> Vehicles that can carry people and supplies for travel through snow</td>
<td>Wooden sled pulled behind the person</td>
<td>Motorized snowmobiles</td>
</tr>
<tr>
<td><strong>Transportation:</strong> Vehicles that can carry people and supplies for travel through water</td>
<td>Canoes made of hollow trees or birch bark</td>
<td>Motor boats</td>
</tr>
<tr>
<td><strong>Transportation:</strong> Apparatus or vehicle for transporting young children</td>
<td>Papoose or cradleboard for carrying child on back</td>
<td>Baby carriages</td>
</tr>
</tbody>
</table>
Basic Human Need

**Clothing:**
Protective shoes for walking through the woods

**Early Invention:**
Moccasins

**Modern Invention:**
Hiking boots

**Shelter:**
Insulating and soft floor coverings for comfort

**Early Invention:**
Hides or hand-woven rugs

**Modern Invention:**
Machine-woven carpeting

**Safety:**
Secure structures to keep dangers out

**Early Invention:**
Homes built on difficult to climb cliffs

**Modern Invention:**
Castles and fortresses
Card Set # 4

Historical Perspective of Inventions

**Preparation:** This set contains six separate subsets of one-sided cards that should be used as separate packs of cards for work. Print the cards in color and cut apart each of the sets of cards and place in labeled envelope.

**Directions:** Each small group of students first arranges the pictorial cards into a timeline. Then they place the cards that describe advantages and limitations below the corresponding cards.
Counting on fingers

**Form and Function**
Fingers move and are raised to keep track by counting all.

Notches on a stick or knots on a rope

**Form and Function**
Notches or knots represent numbers for counting.

Numerals written on surface

**Form and Function**
Numerals serve as mnemonics during mental addition.

Abacus

**Form and Function**
Beads on a frame are moved to calculate sums.

Adding machine or slide rule

**Form and Function**
Mechanical parts calculate a sum.

Electronic calculator

**Form and Function**
Computer chip electronically calculates the sum.
Addition Tool

**Advantage:** Attached to body, so readily available.

**Limitation:** Only have 10 fingers. No way to preserve final sum.

Addition Tool

**Advantage:** Permanent record of counts; more than ten can be represented.

**Limitation:** Very large numbers must be counted and recounted to keep track.

Addition Tool

**Advantage:** One can make calculations by writing on the paper or bark.

**Limitation:** Must do a lot of mental calculation.

Addition Tool

**Advantage:** Can quickly calculate large sums. Beads aid memory.

**Limitation:** May make errors.

Addition Tool

**Advantage:** No errors if operated properly. Fast and can handle large numbers.

**Limitation:** Human operated. Limited size of numbers.

Addition Tool

**Advantage:** High speed; high accuracy; can handle very large numbers.

**Limitation:** Data input by hand.
**Duck or goose quill and ink well**

*Form and Function* Tough, hollow tube that can be shaped to form a pen point and dipped in ink.

**Metal pen tip fitting into a pen holder**

*Form and Function* Strong, durable metal pen tip used with ink for writing.

**Fountain pen with ink cartridge**

*Form and Function* Hollow plastic cylinder contains inner cartridge of ink to supply tip.

**Ball-point pen**

*Form and Function* Ball-shaped writing tip turns in a socket to roll and write; thick ink used to prevent leakage.

**Felt-tip and soft-tip pens**

*Form and Function* A felt or porous plastic tip allows ink to flow from reservoir to allow easy writing.

**Rollerball pens**

*Form and Function* A ball-shaped tip writes smoothly; a wick draws the ink from reservoir to prevent leakage.
**Writing Pens**

**Advantage:** A natural material readily available. Hollow tube holds ink to write a couple of words.

**Limitation:** Tip wears out in a week and must be re-shaped.

**Writing Pens**

**Advantage:** Can be machine-pressed to a specific shape. Lasts longer than a quill tip.

**Limitation:** Must continually dip pen into ink.

**Limitation:** Leaks occasionally, reservoir must be re-filled.

**Writing Pens**

**Advantage:** Less leaks.

**Limitation:** Skips and globs sometimes. Ink is thick must use pressure to write.

**Limitation:** Felt tips become deformed – plastic tips are better.

**Limitation:** More expensive than other common types.

**Advantage:** Very easy pressure-free writing because ink is thin.
**Campfire in rock circle**

*Form and Function*
Smoky, burning wood fire contained by rock circle for heat and cooking.

**Fireplace with iron tools**

*Form and Function* Wood-burning fire in a stone or brick arched area for containment with a chimney for smoke.

**Pot-bellied or cast-iron stove**

*Form and Function* Cast-iron container to radiate heat with a flat top for cooking attached to chimney or stove pipe for smoke.

**Gas stove with burners**

*Form and Function* Metal stove attached to gas line or gas cylinder for fuel. Burners on top direct fire to bottom of pans.

**Electric stove with elements**

*Form and Function* Stove with electric wiring; for smokeless and flameless fuel; coiled elements deliver heat without flame.

**Microwave oven**

*Form and Function* A box-like oven protects people from microwaves; Microwaves excite water molecules to produce heat.
<table>
<thead>
<tr>
<th>Cooking Limitation: Smoky and difficult to control – may send out sparks.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantage:</strong> Simple to construct from natural materials.</td>
</tr>
<tr>
<td><strong>Limitation:</strong> Smoky at times.</td>
</tr>
<tr>
<td><strong>Advantage:</strong> Part of a house – provides heat to home. Contained on three sides and use screen to stop sparks.</td>
</tr>
<tr>
<td><strong>Limitation:</strong> Must start fire and load with wood.</td>
</tr>
<tr>
<td><strong>Advantage:</strong> Fire is contained, much less smoke; top surface for cooking; heats home.</td>
</tr>
<tr>
<td><strong>Limitation:</strong> Cannot use metal food containers.</td>
</tr>
<tr>
<td><strong>Advantage:</strong> can light with a match. Easy to turn on and off. No need to gather fuel. No smoke.</td>
</tr>
<tr>
<td><strong>Limitation:</strong> Hot surfaces; can burn food easily, may start a fire.</td>
</tr>
<tr>
<td><strong>Advantage:</strong> can easily start and stop; less danger of fire.</td>
</tr>
<tr>
<td><strong>Limitation:</strong> Fire danger if elements are left on.</td>
</tr>
<tr>
<td><strong>Advantage:</strong> Food cooks much faster; cold food can be easily re-heated. Timer system shuts heat source off so less fire danger.</td>
</tr>
<tr>
<td><strong>Limitation:</strong> Cannot use metal food containers.</td>
</tr>
</tbody>
</table>
Wash soil in stream

Form and Function
Natural outdoor stream with cold rushing current so that water washes away dirt.

Sponge bath using pottery basin

Form and Function
Cold water from pitcher poured in basin for washing indoors in privacy.

Hand-pump water to sink for washing

Form and Function
Water pumped from well by hand, heated on stove and used in bathtub for warm washing.

Bathtub filled with cold running water

Form and Function
Cold water flows from tap. Extra water must be heated on stove to adjust the temperature.

Bathtub filled from hot water heater.

Form and Function
Both cold and hot (from hot water heater) flow from tap for hot baths.

Built-in whirlpool bath or hot tub

Form and Function
Warm water and whirlpool action clean the body and soothe sore muscles.
**Bathing Limitation:** Little privacy, no soap, water is cold.

**Bathing Limitation:** Must fill and empty pitcher and basin. Generally the water is cold.

**Bathing Limitation:** Must fill and empty heavy tub of water.

**Bathing Limitation:** Warm water must still be heated on the stove.

**Bathing Limitation:** No way to create wave action.

**Bathing Limitation:** Uses a lot of water and energy.

**Advantage:** Stream water is often readily available without preparation.

**Advantage:** Washing can be done in privacy.

**Advantage:** Water heated on the stove makes the bath warmer.

**Advantage:** Cold running water requires little effort to fill and drain tub.

**Advantage:** Both hot and cold running water and easy to drain tub.

**Advantage:** Warm wave action soothes and cleanses the body.
Sheet music

**Form and Function**
Symbols on parchment or paper interpreted and played using musical instruments.

Mechanical music box

**Form and Function**
A cylindrical rotating drum with small metal nubs play a repeating melody on larger musical prongs.

Phonograph records

**Form and Function**
A plastic disk with a long spiraling groove that vibrates a needle riding along the groove to produce music.

Magnetic tape

**Form and Function**
A long plastic, iron-coated tape passes by an electromagnet and is altered by a field caused by sound waves vibrating a wire coil on the magnet.

Compact disk

**Form and Function**
A thin disk of polycarbonate plastic impressed with bumps on a long spiral track is read by a laser and converted to music.

iPod

**Form and Function**
Music is stored as information on a computer chip and converted to music through a player.
Storage of Music

**Advantage:** Can obtain a wide variety; easy to store.

**Limitation:** Must know how to read music and play an instrument. Must have an instrument available.

Storage of Music

**Advantage:** Anyone can play and replay.

**Limitation:** The music is always played by one type of musical instrument.

Storage of Music

**Advantage:** Plays all varieties of music. Can change records to hear different tunes.

**Limitation:** Must have a studio to record. Player cannot be moved while playing.

Storage of Music

**Advantage:** Highly portable instant recording/playback and erasing.

**Limitation:** Wears out and breaks easily, especially if exposed to heat.

Storage of Music

**Advantage:** High-quality recordings last a long time.

**Limitation:** A large collection takes up a lot of space.

Storage of Music

**Advantage:** Thousands of recordings stored in small space.

**Limitation:** Listening to loud music through ear buds may damage hearing.
Observe cloud patterns

**Form and Function**
People watch cloud patterns and recall the weather than usually follows.

Kites used to obtain information

**Form and Function**
A kite floats to the upper atmosphere to collect information to help predict the weather.

Weather balloons

**Form and Function**
A weather balloon floats to the upper atmosphere to collect information to predict weather.

Telegraph info from upwind areas

**Form and Function**
A telegraph brings information from upwind areas to help people see what is coming.

Weather satellites

**Form and Function**
Satellites take wide-range photographs and collect temperature information to help predict the weather.

Computer modeling of weather data

**Form and Function**
Computer programs synthesize data to make statistically valid predictions.
Weather Forecasting

**Advantage:** Can perform without equipment.

**Limitation:** Relies on memory; not very accurate.

Weather Forecasting

**Advantage:** Can sample air from higher levels.

**Limitation:** Dangerous during storms; hard to control.

Weather Forecasting

**Advantage:** Can go quite high and carry equipment for measurements.

**Limitation:** Only samples air in one locality.

Weather Forecasting

**Advantage:** Can determine the weather that is moving toward an area.

**Limitation:** Harder to predict long-range weather.

Weather Forecasting

**Advantage:** Photographs and temperature maps of large areas produced.

**Limitation:** Expensive.

Weather Forecasting

**Advantage:** Information is integrated and more accurate.

**Limitation:** Weather is complex and difficult to model.
Predecessors of Innovations

**Preparation:** These are one-sided cards that should be cut apart and mixed before being given to the student. The first page shows heading cards that should be used at the top of each column. A small group of students should be given this complete set or half of it. Therefore, depending upon class size, several sets will need to be made.

**Directions for Student Work:** Students should work in pairs or small groups of no more than four members. Students’ task is to form a chart-like layout with the cards in each row arranged as shown in the sets here. The order of the rows is not important. Students should use the heading cards to form the columns of the layout.
### Predecessor
- Sweeping the rug clean with a broom

### New Innovation
- Shampooing the rug with a rug cleaner

### Improvements
- Dissolves dried-on dirt
- Vacuums and sucks dirt away
- Removes odors
- No dust left

### Predecessor
- Heating home with fireplace

### New Innovation
- Heating home with furnace

### Improvements
- Cleaner, no ash, smoke
- Less work
- No need to gather wood
- Can easily adjust temperature
Using hair rollers for curly hair

Using a curling iron for curly hair

Faster
Easier
Can re-curl parts that are not curly enough

Candles for lighting

Electric fluorescent lighting

Instant on and off
More light
Cool
Little fire danger

Wild Strawberries

Huge Strawberries selectively bred

Much larger
Firm when ripe
Sweet-tasting
Last longer without rotting
Simple manual toothbrush

Electric Toothbrush
- More brush strokes
- Variable angle
- Easier to use because hand does not tire

Home Remedy for Illness

Prescription Medicine
- Powerful antibiotics kill germs
- Designed to target specific ailments

Paper Grocery Bag

Re-usable Fabric Bag
- Does not require cutting trees
- Reusable
- Stronger and more durable
- Has carrying handles
- More colorful
- Washable
Electric Food Processor

- Less work for cook
- Can chop to desired sizes
- All food bits are contained
- None falling elsewhere
- Less risk of cutting fingers

Mixing with a spoon

- Faster
- Easier
- Mixes smoother
- Whips in more air

Sending trash to a landfill

- Less wasteful
- Saves energy
- Does not take up land space
- Less pollution of groundwater

Metal grater for food shredding

- Recycling plastics, metal, paper
Card Set # 6

Two-sided Animal Form and Function Cards with One-sided Cards of Analogous Manufactured Items

**Preparation:** There are 6 different sets here; one for each of the following animals: alligator, beaver, bluebird, owl, whale, and wolf. The animal cards are two-sided. Glue the card front from the left-hand column to the front of a piece of cardboard and the back side of the card, shown in the right-hand column, to the back of the cardboard. The manufactured object cards are one-sided and should also be glued to cardboard.

**Directions for Student Work:** Students should work in pairs or small groups of no more than four members. Students’ task is to match the front of each animal card to the analogous object card that has the same form and function. After these have been paired, the work can be checked by turning the animal cards over and reading the backs of the cards.
An alligator’s tail is wide and strong. When an alligator swims it uses its tail to push itself through the water.

An alligator’s skin is colored brown, tan, and green to help it blend into its environment.

An alligator has wide flared nostrils that sit above water to help with breathing while hiding under water.

An alligator bellows and growls to communicate with other alligators.

Boat Oar

The boat oar is wide and strong and is used to push through water to move a boat. Similarly, the alligator uses its wide, strong tail for pushing it through the water.

Camouflage Vehicle

Military vehicles, are colored brown, tan, and green to blend into the environment. Similarly, an alligator’s brown, tan, and green colorings blend into its marshy environment.

Snorkel

A snorkel is a wide tube that has an opening that sits above water. People use the snorkel for breathing while under water. Similarly, an alligator has wide, flared nostrils that sit above water to allow the alligator to breath while submerged.

Door Bell

A door bell is pushed to make a noise to signal that a person would like to talk. Similarly, an alligator growls, bellows, or hisses to signal other alligators of danger, or as a sign of being frightened.
**Binder Clip**
A binder clip has a powerful wire hinge that snaps down quickly to capture a set of papers and pinch them together. Similarly, the powerful jaw of an alligator will snap down quickly to capture prey.

**Flippers**
Divers wear flippers that are webbed to help them maneuver in the water. Similarly, the webbed hind feet of an alligator push against water for maneuvering.

**Soda Can Opener**
A can opener is sharp for gripping and puncturing the can. Similarly, an alligator has sharp teeth for gripping prey and puncturing the prey to be swallowed easily.

**Flap on Box**
The flap on a box opens and shuts when we need to put things in or take things out of the box. Similarly, the flap in the alligator’s throat opens and closes, depending on whether it is in the water or needing to swallow its food.
Goggles

Goggles are worn by swimmers to protect their eyes and to allow vision underwater. Similarly, the third eyelid covers an alligator’s eye to protect its eyes while underwater waiting to catch its prey.

Plug on an Inflatable Beach Ball

A plug on an inflatable beach ball keeps air from escaping and water from getting in. Similarly, the movable flap in alligators’ ears allow them to reduce water intrusion while remaining underwater.

Inflatable Raft

The bottom of a raft has a smooth surface for gliding through the water. An alligator’s smooth belly allows it to glide quietly through the water without friction or resistance. This enables the alligator to sneak up on its prey.

Diaper

Diapers have thick padding to prevent liquid from leaking out. Similarly, an alligator has thick dermal skin for the prevention of losing body fluid, which is needed to keep cool.
Beavers have webbed feet with broad surfaces to scoop up mud to put on their shelters.

Shovel

A shovel is a tool with a broad surface used to scoop up earth. Similarly, beavers' feet are webbed to produce a broad surface. They are used like a shovel to scoop mud and place it on the beavers' shelters.

Hand Saw

A hand saw has large, sharp teeth to cut and tear through wood by a back and forth motion. Similarly, a beaver gnaws at a tree taking layer after layer of it off until the beaver cuts all the way through.

Cymbals

Cymbals are large flat, plate-shaped instruments that are slapped together to make a loud noise. Similarly, a beaver slaps its flat tail against the water making a loud sound which tells others of danger.

Beaver shelters are made of piles of logs and sticks stacked and woven together to make a sturdy framework for the beaver lodge.

Basket

A basket is made of many sticks that are woven together to produce a strong framework. Similarly, beavers weave sticks and logs together to make a sturdy framework for their lodges. Then they pack the lodge with mud to make it stronger and waterproof.

Beavers have large flat tails with which they slap the water to create a loud noise that warns of danger.

Beavers have large sharp front teeth to cut down trees and to tear off bark for food.
A beaver's lodge is covered by a thick layer of mud and twigs. This layer insulates the lodge from the cold winter air and keeps the body heat generated by the beavers inside.

Beavers make their shelters in the deeper water of ponds. The pond water is a barrier to the beavers' predators and helps keep them out.

Beavers cover their shelters with mud and twigs. When the mud dries it becomes hard and helps make the shelter sturdy.

Primitive Mud Bricks
A primitive brick is a dried block of mud and grass (clay) which is used in the construction of buildings. In an adobe building, a layer of mud is smoothed over the brick wall to help hold the bricks together and to give a smooth surface. Similarly, the mud used on the outside of the beaver shelters becomes very hard and helps hold the lodge together.

Insulation
A layer of fiberglass insulation is used in the walls of buildings to keep the cold outside and warmth inside. The mud used on the walls of the beaver shelters insulates the beavers from the cold winter air and keeps air warmed by their bodies near them.

Castle Moat
Many castles are surrounded by a deep ditch filled with water - a moat. The moat prevented enemies from entering the castle. Similarly, a beaver builds a lodge in the middle of a pond to keep non-swimming predators out.

Public Fountain Works
Many public fountains have doors to filters and pumps underwater so that people will not disturb them. Similarly, beavers make the entrances to their shelters underwater so that many predators that do not swim will not be able to get inside their homes.
Beavers have webbed feet that provide a broad surface for effectively pushing against the water when swimming.

Bark Mulch on a Playground
The ground around and under many outdoor playgrounds is covered with bark mulch. This layer of wood chips keeps the ground from becoming muddy in wet weather. Similarly, beavers cover the floors of their dens with wood chips to keep them from becoming muddy and to make them more comfortable.

Flippers
Swimmers often wear flippers on their feet to provide a broader foot surface for effectively pushing against the water. Similarly, beavers have webbed feet that effectively push against the water.

Vent
Human dwellings have vents which allow fresh air into the house or apartment. A vent is a hole covered by a screen and often having a fan inside to draw air in or out. Bathrooms very often have vents. Similarly, a beaver’s lodge has a small hole in the top to allow fresh air to circulate.

Hot Glue Gun
A hot glue dispenser takes long cylinders of glue and melts them for use in gluing things together. As the glue is used up, more long cylinders are added so that there is always more glue to be melted. Similarly, a beaver’s teeth never stop growing. As the teeth are worn down, the beaver’s body produces more tooth at the root so there are always teeth for gnawing.

Beavers cover the floors of their shelters with small wood chips. This keeps the interior from getting muddy and makes it more comfortable.
Object: Shovel

Object: Hand Saw

Object: Cymbals

Object: Basket

Object: Mud Bricks

Object: Insulation

Object: Castle Moat

Object: Public Fountain Works
Object: Bark Mulch on Playground

Object: Flippers

Object: Vent

Object: Hot Glue Gun

Beaver
Form and Function Analogy Object Box
Designed by Kevin Shepherdson
Edited by Dr. Audrey Rule
Assembled by _____________________

Box Labels
Bluebirds can position their tails at different tilts to help control their movement as they fly.

Airplanes have a part called a rudder which can be positioned in different ways to control the plane’s movement. Similarly, bluebirds can position their tails to help them as they fly.

A raincoat is made of waterproof fabric to repel water so that the wearer can go out in rainy weather and stay dry. Similarly, the bluebird feathers repel water to help the bird stay dry when it is raining.

A bluebird’s skeleton is made of lightweight, hollow bones that support the body, without contributing excess weight.

Bicycle frames are made of lightweight, hollow cylinders that provide the support without adding much weight. This allows riders to travel more efficiently and quickly than walking. Similarly, bluebird skeletons have lightweight, hollow bones that provide the support necessary for flight.

Male bluebirds have bright blue plumage which attracts the female bluebird.

Many advertisements use bright colors and bold patterns to attract customers. Similarly, male bluebirds’ bright plumage attracts female bluebirds.
Clothespins

Clothespins are designed to grip the clothesline securely when the spring is relaxed, so that the clothes are always held tightly in place. Similarly, the muscles in a bird’s feet are relaxed when they are in a position of gripping a branch.

Tongs

Tongs consist of two parts that are pressed together to pick up objects. Similarly, a bluebird can pick up worms and bugs with its beak.

Smoke Detector

The smoke detector makes a raucous screech when it senses smoke to warn inhabitants of a home about danger of fire. Similarly, the bluebirds make a raucous screech when they sense danger to warn others.

Airplane Wings

An airplane’s wings are thin, flat, broad surfaces that enable the aircraft to fly quickly through the air. Similarly, bluebird wings spread out to enable the bird to fly through the air.
A female bluebird has a special marking - a white ring around each eye that distinguishes her from the males. This way, bluebirds can tell each other’s gender.

The bluebird’s small body size, wing shape, and flapping wing motion makes it one of the few birds that have the ability to hover to look for insects.

A bluebird's nest is woven of grasses and twigs to make a cup-shaped container for eggs.

Bluebird eggs are kept at a constant warm temperature in the nest for necessary chemical changes to take place for the baby birds to grow.

A bluebird's nest is woven of grasses and twigs to make a cup-shaped container for eggs.

Restroom Signs
A ladies’ restroom sign shows a special marking - the silhouette of a woman wearing a skirt. This way, people can tell which gender uses which restroom. Similarly, female bluebirds have different markings than male bluebirds.

Cookies
Cookie dough must be kept at a constant warm temperature in the oven for the necessary chemical changes to take place for cookies to bake. Similarly, eggs are kept at a constant temperature to aid chemical changes needed for growth.

Rescue Helicopters
The helicopter’s rotor blades allow it to hover to look for people who need to be rescued. Helicopters are one of the only flying machines that have the ability to hover. Similarly, bluebirds are able to hover to look for insects to eat.

Woven Basket
Most baskets are made from twigs, grasses and other natural materials that are woven into a cup-shaped container. Similarly, bluebirds gather natural materials from their environment to make their nests.
Object: Restroom Sign

Object: Cookies

Object: Helicopter

Object: Woven Basket

Bluebird
Form and Function Analogy Object Box
Designed by Christine Morgan
Edited by Dr. Audrey Rule
Assembled by _____________________
Owls have very sharp and well-focused eyesight that helps owls see their prey in the dark.

The neck joint allows the owl’s head to rotate as much as 270 degrees. This enables owls to watch a moving object in all directions without moving the whole body.

When the wings of an owl are open, they have a wide, broad surface that pushes against the air to help with flight.

Facial disks are round, cupped surfaces around the eyes of an owl. They are designed to help an owl to hear better by bouncing sound waves into the ear.

Binoculars
The binoculars make images of things far away sharper and better focused so that they are easier to see. Similarly, the eyesight of an owl is sharp to help them see their prey better at night.

Oscillating Fan
An oscillating fan has a swivel joint that allows the fan to rotate about 270 degrees to blow air in all directions of a room. Similarly, an owl is able to move it’s neck 270 degrees to search all areas.

Hand Held Fan
When a hand held fan is open, it creates a wide, broad surface that pushes air to cool people. Similarly, the wide, broad surface of an owl’s wings allows the owl to glide through the sky by pushing against the air.

Cupping Hand Around Ear
A person can hear better if the person cups his/her hand around the outer ear. Sound waves are gathered by the round surface of the cupped hand and bounced into the ear. Similarly, the facial disks on an owl help to make sound louder by bouncing sound into the owl’s ears.
Cheerleader Pompom

Cheerleader pompoms are bundles of long fibers that are waved to show emotion to others. Similarly, the ear tufts on an owl are long and can be positioned to show the mood of an owl.

Coat

Coats have fibers that trap air next to the body and repel rain to allow the wearer to endure different types of weather. Similarly, feathers on an owl protect it in different types of weather. Short feathers keep out extreme heat and cold, and long feathers repel rain.

Padlock

A padlock has a curved bar or shackle that encircles a hasp or ring to securely hold on. Similarly, the claws of an owl encircle a branch to grip to perch securely and not fall off.

Police Officer

Many police officers are active at night to prevent crime during late hours. Police officers sometimes conceal themselves in dark places to catch criminals. Similarly, because owls are nocturnal (sleep during the day and active during the night), they can use their super senses to help them sneak up on and catch prey.
The feathers on an owl are soft and downy. They are used to muffle airflow and create almost silent flight.

The feathers on an owl are multicolored (brown, black, tan, gray, white). Their colors help them to blend in with leaves, branches, and trees.

The talons on an owl are curved, thin, and sharp. They are used to grip and pierce their prey.

The beak on an owl is long and hooked. It is used to poke and grab bits from its prey prior to swallowing.

**Ear Plugs**

Ear plugs are made of a soft rubber that absorbs sound waves. They are used to muffle loud sounds. Similarly, the feathers on an owl help to muffle sound when hunting for prey at night. Owls rely on silent flight to sneak up on prey.

**Camouflage Clothing**

Camouflage is a cloth pattern that military people wear. It is multicolored (green, tan, brown, and black) to help them blend in with trees, leaves, and bushes. Similarly, the various colors on an owl help them to blend in with their surroundings when hiding from their enemies.

**Hair Claw**

A hair claw is curved, thin, and sharp. It grips into hair to hold it in place. Similarly, owls use their talons to grip and pierce into their prey.

**Crochet Needle**

A crochet needle is long and hooked to poke and grab yarn when crocheting. Similarly, the beak on an owl is long and hooked to poke and grab at its prey.
Bicycle Training Wheels

Training wheels on a bicycle _help a child balance the bike_. The _wheels_ distribute some of the weight farther from the central axis and provide extra surfaces for balancing the bike on the road. Similarly, a whale has side fins to stabilize it in the water.

Push Broom

A _push broom_ has a brush made of _long stiff fibers_. These _fibers trap and push dirt_ ahead of the broom. They allow air to pass through the bristles, but dirt cannot. Similarly, the baleen fibers trap krill and other foods while water passes through.

School Bus

A _bus_ is a _form of transportation in which children travel the same route_. Children ride a _bus to socialize and for mutual protection_. Similarly, whales travel together in the same group.

Whistle

People may use a _whistle_ to _communicate with one another over a large crowd or long distances_. Similarly, whales use a whistling sound to communicate with each other over long distances.
**Snorkel**
A snorkel is a passage through which a swimmer can breathe. Similarly, a whale blows out and takes in air through the blowhole.

**Cage**
A cage has bars that prevent small animals from escaping. Similarly, a whale’s baleen holds food in the mouth until it can be swallowed.

**Jacket**
A jacket is a layer of different materials that hold pockets of air next to the body for insulation, keeping a person warm in cold weather. Similarly, a whale has a thick layer of blubber just below the skin to insulate its body.

**Milk Bottle**
Milk bottles contain milk and have nipples to feed young children. Similarly, whales have mammary glands that contain milk and teats for feeding their young.
A camera has a very small aperture, but can produce a clear picture with the light it receives. Similarly, a whale's eye is small but allows for excellent eyesight.

Bellows is a device for producing strong air currents that consists of a pleated chamber that expands and compresses to force air out through a hole. Similarly, a whale's underside expands as the whale takes in a large volume of water.

White craft glue is a sticky, fast-hardening substance that seeps into pores. It can be used to permanently attach paper items together. Similarly, barnacles secrete a substance to cement their shells to the whale's skin.

A bicycle's pedals are physically moved up and down to propel the bike. Similarly, the whale's flukes move up and down to enable a whale to move through the water.
**Whale**

Form and Function Analogy Object Box

Designed by Lisa Carson
Edited by Dr. Audrey Rule

Assembled by _____________________

Box Labels
A wolf’s undercoat is thick, soft, and dense. The undercoat protects a wolf’s skin from extreme heat and cold.

A “Do Not Enter” ribbon is long, flexible, and can be positioned in different ways when it’s used. The ribbon communicates to people that they should not cross into the marked area. Similarly, a wolf’s long, flexible, tail can signal to another wolf not to trespass into its territory.

A wolf’s tail is long, somewhat flexible, and carried in different positions. A wolf uses its tail to signal and communicate with others.

A wolf’s den is typically completely enclosed with an opening on one side. The enclosed den is a shelter for resting and a safe place for pups.

Wolves have toenails that are small, pointed, cupped, and curved. They are used to dig for prey or to dig holes to bury things.

A garden claw is small, pointed, cupped, and curved. People use small garden claw to dig holes in their gardens for planting. Similarly, wolves’ toenails are small, pointed, cupped, and curved and are good for digging.

A potholder is thick, soft, and dense. It is designed to protect a person’s hand from extreme heat. Similarly, the thick, soft, and dense undercoat of a wolf protects the wolf’s skin.

A birdhouse is completely enclosed with an opening on one side. A bird uses a birdhouse as shelter for rest and from weather, and protection for young. Similarly, a wolf’s den is an enclosed space with one opening that is used as shelter for resting, from weather, and for protection of young.
**Police Car**
A police car travel long distances at high speeds to chase down a speeding car. Similarly, a wolf’s ability to run long distances at high speed allows it to chase down prey to feed its pack.

**Cell Phone**
A cell phone makes a loud, high pitched noise to communicate with the cell phone’s owner that there is an incoming call. Similarly, a wolf has a loud, high pitched howl that communicates with any wolves, animals, or people who can hear it.

**Fork and Knife**
Forks and knives have sharp points and edges to rip and tear food for humans. Similarly, wolves use their sharp incisor teeth to rip and tear their food.

**Rain Coat**
Rain coats are long and smooth. They repel rain and snow to help keep people dry. Similarly, the long and smooth topcoat of a wolf repels rain and snow to help keep the wolf dry.
Satellite Dish
A satellite dish is cup-shaped, points towards the sky, and moves to gather waves. A satellite dish then communicates the signal it receives to a television set. Similarly a wolf’s ears are cupped to gather sound waves.

Smoke Detector
A smoke detector’s sensory system is so keen it can detect smoke in a burning house early enough for everyone to get out to safety. A smoke detector senses smoke in much the same way a wolf can smell its prey.

Tool Set
A tool set consists of several different tools that are used together to solve household problems. Similarly, a wolf pack has members that work together to solve their problems of providing food and caring for the young.

Washcloth
A wet washcloth has a large, flexible surface and is used to clean food and liquids from the face. Similarly, wolves will use their tongues to clean the dirt off of themselves and their pups.

Wolves have cupped ears that point upward and move to gather sound waves. They also use the position of their ears to communicate to other wolves.

Wolves live in groups called packs. A pack usually consists of 4 to 7 members. The members of a pack work together to solve problems such as getting food.

A wolf has a nose with such a keen sense of smell that it can detect its prey up to a mile and a half away!

Wolves use their long, flexible, wet tongues to lick liquids and dirt from their faces and to clean their pups.

Wolves have cupped ears that point upward and move to gather sound waves. They also use the position of their ears to communicate to other wolves.
Form and Function Inspirational Ideas for New Products

Preparation: These are one-sided cards that should be cut apart and mixed before being given to the student. The first page shows heading cards that should be used at the top of each column. A small group of students should be given this complete set or half of it. Therefore, depending upon class size, several sets will need to be made.

Directions for Student Work: Students should work in pairs or small groups of no more than four members. Students’ task is to form a chart-like layout with the cards in each row arranged as shown in the sets here. The order of the rows is not important. Students should use the heading cards to form the columns of the layout.
Inspirational Idea

Form and Function

Inventor

New Product
Inspirational Idea

A waffle iron produces a pattern of squares as the batter cooks.

Form and Function

A liquid fills square holes in a mold to produce a square pattern.

Inventor

Oregon Coach Bill Bowerman who wanted his track athletes to perform better. He co-founded Nike.

New Product

Rubber was poured into a mold to make a waffle-soled shoe. This sole allowed athletes better traction and cushioning.
New Product

Hyperball computer with numerous processing nodes that are spherically connected to calculate global warming effects.

Form and Function

Points on the surface of a sphere are all equally distant from the center.

Inspirational Idea

Thinking about how many things in nature are spherical, including the Earth.

Inventor

Dr. Philip Emeagwali, born in Nigeria, now living in the United States. He is interested in super computers.
Inspirational Idea

Images and letters on coins were made by pressing a die (metal stamper) into the metal. Could this idea be applied to making letters on paper?

Form and Function

The shape of a die (a metal stamper) is produced on a flat surface by stamping.

Inventor

German printer Johannes Gutenberg was interested in printing papers and books more quickly.

New Product

The printing press had metal letters that could be arranged to form words. These were inked and pressed onto the paper to make many copies.
Inspirational Idea

People in small apartments in New York City need compact furniture to make the best use of the space.

Form and Function

Hinges in the furniture allow a bed to be folded into a writing desk to make the best use of limited space.

Inventor

Sarah E. Goode was a former slave and the first African-American woman to hold a U.S. patent.

New Product

Folding Cabinet Bed, U.S. Patent Number 322,177; issued July 14, 1885
**Inspirational Idea**

As steam builds inside the pot, the lid **vibrates with the pressure**.

**Form and Function**

Steam produced by hot liquid takes up more space and **produces pressure**.

**Inventor**

Scottish Mechanical Engineer **James Watt** was fascinated with steam.

**New Product**

Steam engines **were powered by steam pressure**.
Inspirational Idea

A customer complained that the French fries were too thick. As a joke, Chef Crum cut the potatoes so thin they could not be eaten with a fork.

Form and Function

The thin, crispy potato chips crunched in a pleasing manner. Customers loved them.

Inventor

George Crum was a Native American/African-American chef at a restaurant in Saratoga Springs, NY in 1853.

New Product

Potato chips were thin and crispy to delight customers with a new snack.
Inspirational Idea

A coiled loop of a flexible garden reminded the inventor of a wheel.

Form and Function

A long fluid-filled cylinder made of flexible material can be bent into a circle and used to cushion impacts.

Inventor

Scottish Inventor John Dunlop with a young son who liked to ride a tricycle.

New Product

The first air-filled tire was made for the inventor’s son’s tricycle. The inventor wound an air-filled piece of a garden hose around the wheel and covered it with a rubber tread. The tire now absorbed shocks.
Inspirational Idea

Soaring birds twist their wings to retain balance while flying.

Form and Function

Curved surface deflects air giving lift and stability to vehicles.

Inventors

The Wright Brothers wanted to build and fly planes.

New Product

Warped wings on aircraft for lift and stability.
Inspirational Idea

A cat clawing at chickens through a wire fence and only pulling feathers through the fence sparked an idea of separating cotton seeds from cotton fibers.

Form and Function

Flexible cotton fibers are pulled through a grating by claws or a comb.

Inventor

Former American farm laborer Inventor Eli Whitney who wanted to improve agriculture

New Product

The cotton gin separated cotton fibers from the seeds that were tightly attached. The comb reached through a grating to pull out the cotton fibers, leaving the seeds.
Inspirational Idea

A telescoping shower head adjusts to different heights and distances from the showering person.

Form and Function

The device is jointed so that length or distance of parts can be finely adjusted.

Inventor

NASA Engineer James Crocker wanted to fix the Hubble space telescope by putting on adjustable lenses.

New Product

Automated arms that could be adjusted were used to position the mirrors at the exact distance needed to repair the Hubble Space Telescope.

http://www.nasa.gov/mission_pages/hubble/story/
Inspirational Idea

Wet leaves *stacked and packed* in a rain gutter with *none broken or damaged*, but all of them bent into a curved shape.

Form and Function

The flat shapes are warped into *saddle shapes* (two opposite sides bent up while the other two sides are bent down) and *stack closely together*.

Inventor

Frederic Baur, an American chemist and food storage technician.

New Product

Pringles chips have a *saddle shape* that *allows them to stack*.
Inspirational Idea

Cockleburs have hooks that stick to dog’s fur

Form and Function

Small hooks of burs become attached to looped fibers of fur or fabric.

Inventor

Swiss Engineer George de Mestral who liked to walk the fields with his dog.

New Product

Velcro fasteners are made of a looped fiber tape and a tape covered in hooks that stick together.