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Caps: A Never Ending Resource In Teaching and Learning in STEM/STEAM Education

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Abstract: With amazing frequency, most of us will open a bottle or other container and throw the cap away without thinking that it has any other use. However, while the end function of a cap is the same for almost all types and materials, caps use various mechanisms to achieve their main function, and come in a wide variety of materials, shapes, colors and other properties related to engineering and technology. For a teacher, caps can have a multitude of educational and pedagogical uses. In this "Caps: A Never Ending Resource in Teaching and Learning STEM/STEAM Education" project, we offer readers, teachers, and students some tools for understanding and using caps as valuable resources for teaching and learning various topics in STEM fields as well as to motivate students to engage in their own learning process as well as a pathways for introducing students to some concepts and applications in engineering and technology. In addition, we provide detailed instructions, including some hands-on activities that will help teachers master the concepts and the pedagogy.
Keywords: Caps, STEM/STEAM, Design, Instruction, Effective Learning, Hands-on Learning

I. INTRODUCTION

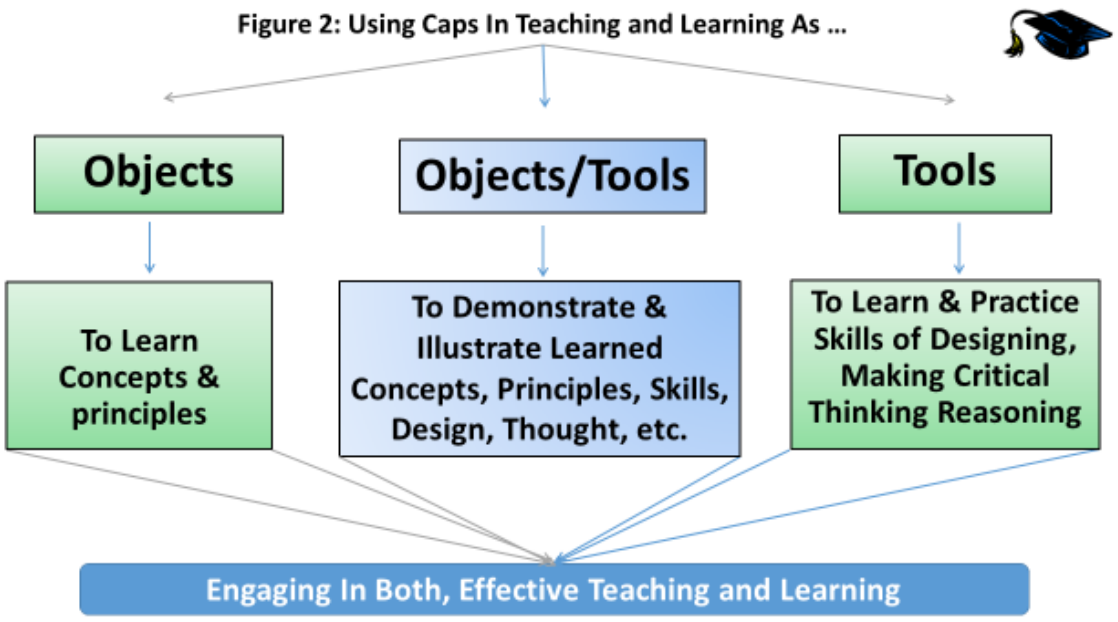
Almost every week, most of us will open a jar or bottle and throw the cap away without thinking of any value it might have other than keeping the contents sealed tightly inside. However, bottle caps and jar lids are very fascinating objects, from many perspectives including design, mathematics, engineering, and technology. They come in different sizes, shapes, designs and levels of designed complexity, functions, colors and patterns and are made of a variety of materials (Figure 1). In addition, while the end function is the same for almost all types of caps, they use various mechanisms to achieve that function. For teachers, they can have a multitude of educational and pedagogical uses that help create learning pathways which work with a variety of students' interests and needs (Figure 2), and help remove potential barriers that deny many learners equal access to excellence and success in STEM and other fields ([1], [2]).

Caps are very useful for introducing students to many central STEM concepts, as well as effective tools for improving writing and language arts skills. They can be used to develop observational and classification skills by sorting them into different colors, compositions (metal, plastic, etc.), sizes, weights and densities, construction, levels of designed complexity, and numerous other properties. With them you can illustrate mathematical concepts like addition, subtraction, division and multiplication, ratios, fractions, percentages, proportions, statistics and graphs. Through the study of caps' designs and levels of complexity, algorhythmic concepts and skills could be introduced, learned, and applied. Caps can also be used to introduce the concepts of color theory and primary and secondary colors. They can be applied creatively for arts, crafts, jewelry, buttons, or to create games, toys, and even music. They can be used to study the relationships between shape and design or structure and function. They can be used to study and differentiate between metals and non-metals and between magnetism and electricity. They can be used to study engineering and graphic design. The list of uses is nearly endless in both STEM and non-STEM fields.

In designing a given cap, STEM concepts repeatedly appear, from physical and mathematical concepts to graphic design, selecting the right construction materials, the correct shape, appealing aesthetics (the best color, luster and form for visual appeal). All these characteristics have to fit and complement each other to achieve the main function of a given cap, and also to communicate any hidden message the designer wishes to convey to consumers and users of the product. In addition, all the characteristics must be described in written form, accurately and in detail, for all those who are involved in the process, from the designers to the manufacturers, and from the decision makers to salespeople, to name a few. When we study caps carefully, our perception of them changes. Instead of simple, insignificant objects that we casually throw away, they can become sophisticated and significant artifacts that we save, reuse and recycle.

Figure 1
Bottle caps and jar lids are made of a variety of materials and come in different sizes, shapes, designs and levels of design complexity, functions, colors, patterns, etc.

Source: http://sencer.net/wp-content/uploads/2016/12/Caps-A-Never-Ending-Resource-In-Teaching-and-Learning-In-STEM-STEAM-Education.pdf[2]



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By looking at table 1, we can see, for example, into how many categories, sub-categories, and subsequent sub-categories caps can be grouped. Teachers can ask students to divide caps into as many categories as they are able. Then, the teacher can use each category as a starting teachable point to introduce a given scientific, mathematical, and or engineering concept. For example, in the color classification, the class could investigate the differences between colored pigment and colored light, how we perceive color, how color

is created or how colors are mixed. Students can also be asked to research the history of specific pigments and dyes, how colors have been used in our society or in the past, and many other fundamental topics.

If the students classify caps by the material from which they are made, teachers can introduce the concept of metals (such as copper, iron, aluminum, etc.) and nonmetals (wood, plastic, cork, etc.), and how they differ from each other. They can explore which caps conduct electricity or can be magnetized, and which ones cannot. They can classify matter according to its composition, whether pure substance (elements, compounds), or mixture (heterogeneous or homogeneous), and use this as a springboard into the nature of matter, such as atoms, molecules, and chemical reactions. They can even learn about world politics and globalization by looking at resource scarcity and its relationship to global resource distribution [3]. Teachers and students can also investigate the relationship between design, function, and aesthetics.

Caps can also present serious, worthwhile conceptual challenges to students. For example, how would you define or describe caps? How do you differentiate between caps, lids, and tops? Can you draw various kinds of caps in two and three dimensions? How can you design and build a cap that has only one function and a cap that has multiple functions? How can you make transparent, translucent, and opaque caps? How is color added? What are the advantages of caps that screw onto the outside of a bottle opening compared to those few that screw into the inner surface, or are forced into the bottle top, such as a cork? What are some of the limitations and challenges in using a given material for designing and creating caps? Below are a few samples of activities that will address some of these questions.

When you think of caps you also need to keep in mind that today, students come to schools with diverse interests, strengths, needs, and goals. Our job as teachers is to know our students, to be aware of their strengths and weaknesses, and to reach them in different ways using familiar objects and proven teaching methods that work with a variety of students in gaining desirable skills, acquiring meaning, and transferring knowledge [4].

What we need to keep in mind is that:

> Curriculum should not only focus on the tools necessary to develop reasoned and logical construction of new knowledge in our various fields of study, but also should aggressively cultivate a culture that nurtures creativity in all of our learners. Out-of-the-box – or no box – thinkers should be valued as we begin drafting creative designs for our curriculum and our schools. … In our work to improve education, we need to be bold advocates for creative ideas that are actionable, rational, and constructive. [5, p.40]

Using caps pedagogically in the learning processes can help free the imagination, ignite the start of creative thought, and motivate engagement in the learning process among many students. After all, as K. Patricia Cross (1999) from the Alliance For Community College Innovation, explained “Learning Is About Making Connections --whether the connections are established by firing synapses in the brain, the "ah ha" experience of seeing the connection between two formerly isolated concepts, or the satisfaction of seeing the connection between an abstraction and a "hands-on" concrete application” [6, p.5].

II. WARM UP ACTIVITY

To stimulate students’ minds and prepare them for working with caps, students are asked to engage in this warm-up activity which is designed to be conducted a few days before asking students to engage in hands-on activities with caps. In this phase, the teacher interacts with students mostly as a facilitator for the discovery process by asking questions that will help guide the students through the process and apply their learning. Simpler questions are at the beginning, more advanced towards the end; you should select a few questions based on the level of your students.

Working individually, ask each student to:

1. List all the materials that a cap (or other object) can be made of.
2. List all the colors that you can think of.
3. List all the shapes that a given object can be made into.
4. List all the shapes that can be considered natural, as seen in nature.
5. List all the colors that you don’t think are natural, meaning not seen in a natural environment.
6. List all the materials you can that you think don’t occur naturally, meaning they are human-made materials.
7. Define the word “definition”, “structure”, and “function”.
8. Differentiate between elements, compounds and mixtures.
9. Differentiate between heterogeneous and homogenous substances.

10. Identify at least 3 things that are made up of pure substances (elements or compounds).
11. Identify at least 3 things that you think are made up of mixtures of pure substances.
12. Differentiate between solids, liquids, gases, and give an example of each.

Write down your answers of these questions and end your report by writing one or two paragraphs on what have you learned from this activity. By completing this warm-up activity, teachers can ensure that all students have some level of a shared vocabulary which is one aspect of successful communication that is needed for effective learning and collaboration among students and between students and teachers [7].

III. LEARNING ACTIVITIES

III.1. Activity I: Let's Define Caps

A definition is a statement of the meaning of a word, a phrase, or a term that stands for something that can be physical or conceptual. Most of the dictionaries that students use in school or at home don't define caps. This makes this activity an intriguing educational challenge. Without an agreed upon definition for caps, students might have a difficult time communicating with each other effectively while using the caps to explore various subjects. With this in mind, the following activity is designed to help students to talk, listen, read, write, and reflect as they become directly involved in the search for a meaningful definition for caps that distinguishes them from other similar objects such as lids and tops. Engaging students in instructional processes such as these promotes critical thinking and improves the overall quality of learning. The procedure is very simple:

1. Divide the students into groups of four.
2. Give each group a number of different caps that differ in color, size, shape, design, complexity and the material(s) of which they are made.
3. Ask the members of each group to examine each cap, and then describe each one in writing according to:
    - Structure
    - Function
    - Both structure and function
    - Other
4. Ask each group:
    - To choose or revise their descriptions of each cap so that all the members agree on one definition.
    - To identify whether their final definition of cap is a functional definition, structural definition, both or neither.
    - To identify the challenges they encountered in defining and/or devising a definition for caps?
    - To try to explain why most dictionaries don't provide definition for caps.
5. Write down your answers to these questions and end your report by writing one or two paragraphs on what have you learned from this activity.
6. If you had to re-do this activity all over again, how would you do it and why?

The following are Examples of Students' Definitions of Caps:

1. A cap is an object that encompasses or covers an object (specific to the container) to prevent a substance from spilling out. Most commonly seen as circular, they can have many shapes, be many sizes, and are made out of many different materials that are sturdy enough to execute the definition.
2. It is something we use to cover or seal different kinds of containers. They are made of different materials (i.e. plastic, metal, wood, etc.). Their shape varies depending on the nature of the container. They usually are made to prevent an object or substance from getting out of or in to the container.
3. It can be metal or plastic, or cork, or wood. They come in various sizes, shapes, and colors. Their primarily use is to cover containers, bottles, jars, etc. They help keep things from spilling, keeping them fresh and safe in the container by preventing things from going in or out of the container.
4. A circular piece that serves as a sealer for bottles and containers to maintain its contents, preserving its flavor, freshness, dryness, etc.

III.2. Activity II: The Power of Prediction in Fostering Critical Thinking

To predict is to "state, tell about, or to make known in advance, especially in the basis of special knowledge; to foretell" [8, p. 1032]. In this sense, forcing students to engage in the prediction process meaning that we are forcing them to use their previous knowledge and experience as well as critical thinking to imagine what would happen or what they would see, and to provide a cognitively informative prediction. The following activity is designed with this goal in mind.

Prior to engaging student in this activity, the teacher needs to prepare zipper sealed plastic bags (10 x 11 inches or bigger) or containers each with various types of caps (color, size, design, structure, make-up, etc.). Make sure that each bag has a different number of caps (somewhere between 30 and 50).

1. Divide the class into groups of 4 students.
2. Give each group zipper sealed plastic bags (10 x 11 in or bigger) or containers.
3. Ask the members of each group, without opening the bag to examine and be familiar with the caps to estimate the total number of caps in the zipper sealed plastic bag using the following approach:
    a. It doesn't have more than …… caps.
    b. It doesn't have less than …… caps.
    c. Our estimated number of caps (average number between more than and less than) would be …….. .
4. Ask the members of each group, without opening the bag to examine and be familiar with the caps to predict:
    a. How many metal caps are there?
    b. How many non-metal caps are there?
    c. How many plastic caps are there?
    d. How many wooden caps are there?
    e. How many cork caps are there?
    f. How many aluminum caps are there?
    g. How many copper caps are there?
    h. How many steel caps are there?
    i. How many small size caps are there?
    j. How many medium size caps are there?
    k. How many large size caps are there?
5. Ask the members of each group to present their prediction of each item in #4 in both numbers and percentage or numbers and graph.
6. Upon completion, ask the members of each group:
    a. To test their predictions by opening their zipper sealed plastic bag, and counting each identified item in step #4.
    b. To present their findings of each item in #4 in both numbers and percentage or numbers and graph.
7. Compare and contrast between their predictions and their actual findings.
8. Each group member should write down their answers for these questions and end their report by writing one or two paragraphs on what have they learned from this activity.

III.3. Activity III: Caps Material Make-up.

Divide the class into groups of 4 students. Give each group a bag or a container with various types of caps. Ask the members of each group to examine and be familiar with the materials that caps in the bag they have are made up of.

How many different materials are each of your caps made of? There are two tables below, table 1 to record the materials(s) that the caps are made of, and table 2 to record the number of different materials in each cap. Use the tables below to record your findings, and then answer the questions that follow. Finally, the members of each group, should write down what they have learned from actively engaging in this activity including what surprised them the most and the least of their findings and why.

Hint: plastic, wood, cork, glass, steel, aluminum, rubber, copper, brass, tin, etc.

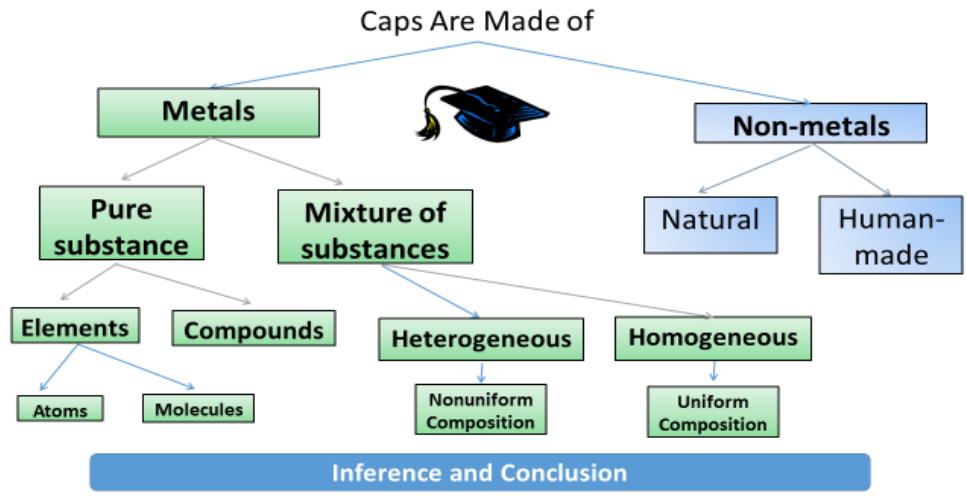
Table -1-
Caps Material Make-up

Materials	Examples	Availability of the Sample (many, some, few, rare)	Color	Additional Information
Plastic				
Steel				
Aluminum				
Cork				
Glass				
Ceramic				
Copper				
Wood				
Other				

Table -2-
Number and Type of Components in a Given Cap

Number of Components (material)	Number of Caps	Components Type of Material(s)	Additional Observations
One Material	3	plastic	Cap has inner opening
Two Materials	2	Metal (tin?) and cork	Cap is screw-on type
Three Materials			
Four Materials			
Five Material			
Five + Materials			

Figure -3-



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III.4. Activity IV: Dual Function

One of the fascinating thing about caps is the fact that, beside their main function, many of them have additional essential functions without which the intended caps cannot be fully functional. For example, the fabric refresher bottle cap or the air freshener container cap is more than to maintain the content within the bottle or the container. It is also the device through which the content can be spread onto the air or on clothing items in a desirable fashion. The following activity is designed to help students discover the multiple functions of some caps and the relationships between design, structure, and function.

Divide the class into groups of 4 students. Give each group a zipper sealed plastic bag or a container with various types of caps. Ask the members of each group to examine and become familiar with the function of the caps in their container, and then work together to answer the following questions:

1. Identify those caps which function as a two-way (or more) cap for a given container and or bottle.
2. What is the percentage of caps that function in more than one way?
3. Come up with a hypothesis why this type of cap is designed as a two-way cap.
4. Do Internet research to discover why this type of cap is designed as a two-way.
5. Does your hypothesis agree or disagree with your findings?
6. How would you modify your hypothesis so it could lead to the findings that you have obtained?
7. Write down your answers of these questions and end your report by writing one or two paragraphs on what have you learned from this activity.

III.5. Activity V: Caps In the Learning Environment

1. Discuss with the members of your group what you might do with caps in your home, in your life, and in your classroom?
2. List all the possibilities that you have identified in question 1.
3. Select and describe in detail two of the possibilities of how you might use caps in in your home, in your life, and in your classroom as listed in question 2.
4. Write down your answers of these questions and end your report by writing one or two paragraphs on what have you learned from this activity.

III.6. Activity VI: Let's Classify Our Intriguing Caps

Classifying is assigning objects to classes indicating like similarities in structure, function, etc. The ability to study and examine objects and systematically group them into informative certain categories and sub-categories based on shared characteristics requires, a combination of developing understanding of various important and worthwhile matters of the intended objects. The result of classifying process is concept, idea that compare and contrast things, events, or describe causal relations among them ([9], [10]).

Brainstorming is always a good way to arrive at effective ways to classify anything, including caps. Finding interesting secondary functions for caps is only one category students might consider.

1. Discuss with the members of your group how many different categories, sub-categories, and secondary sub-categories you can use to classify the caps in front of you?
2. List all the possible categories, sub-categories, and secondary sub-categories that you identified in question 1.
3. Using the caps in front of you, try to illustrate each category, sub-category, and secondary sub-category that you listed in question 2.

Below are examples of possible categories for classifying caps, sorted by categories such as color, substance, density, and function.

III.6.1. Ways to Classify Caps: The following are only a few of the ways that can be used to classify caps for pedagogical reasons.

- Resemblance: similar caps vs. non-similar caps
- Material make-up: metal vs. non-metal caps
- Color: colored vs. colorless caps
- Size: small, medium, or large caps
- Weight: light, medium, heavy caps
- Density: low density, medium density, high density
- Transparent, translucent, or opaque caps
- Design: simple vs. complex design
- Shape: cylinder, tapered, cone-shaped, complex shapes, non-circular shapes
- Toughness: scratchable vs. unscratchable by different materials
- Function: single function vs. dual or multiple function
- Sealing mechanism: screw in, screw on, push/pull

III.6.2. Categories

In the table below, you will find examples of categories (such as color, material, and shape) that your students can use to classify their caps. Have them fill in the table with the caps that each group has selected.

Table 3: Examples of categories students can use to classify their caps

Category	Sub-Category	2nd Sub-Category	Examples
Color(s)	Primary Color or Non-Primary	Translucent or Transparent	
Material(s)	Metallic Non-Metallic	Magnetic Non-Magnetic	
Density	Floats or Sinks in Water	Light Medium Heavy	
Size	Small Medium Large		
Shape	Circular/Cylindrical Rectangular/Square Triangular Cube, Sphere Other		
Volume	Large, Medium, Small		
Height	Tall, Medium, Short		
Groove	Many, few, none		
How it Seals the Container	Push & Pull Screw on Snap on		
Caps with Ads	Writing on Cap	Illustration on Cap	
Two-Way Caps +	Two-way Caps	Three or more functions	
Level of Designed Complexity	Simple Moderate Complex		
Other Criteria	Possible uses,		

III.7. Activity VII: Invention and the Creative Uses for Caps

To invent is to conceive of an idea, to create, devise or generate something that is new to the creator. Because of their ease and plentiful availability as well as their diverse make up, shape, color, size, etc., caps are good objects for triggering the students' minds and freeing their imagination to be creative in endless possibilities.

This is where brainstorming with your students can be useful. Divide the students into groups and have a competition to see which group can invent the most interesting, useful, or unusual use for caps. They can use any of the above categories or a category of their own. You decide how long they have for their invention/creation, and what tools and supplies they can use; (tape, wire, glue, drill, saw, non-cap materials, etc.).

III.7.1. Possible Secondary Cap Uses:

- Make jewelry
- Use as buttons
- Make toys or games
- Create musical instruments with the caps
- Art project (building structure), collage, crafts, mold device
- Make miniature furniture
- Make wheels
- Make chips for games, pins for hair
- Decorate picture frames or flowerpots
- Study shape and design, structure and function

- Use as containers
- Use as objects to illustrate and re-enforce mastering of cognitive skills such as adding, subtracting, multiplying, dividing, percentage, ratio, graphic, etc.
- Use to study design, and the relationship between shape, structure, and function

III.7.2. Conversation with an Industrial Designer

While caps have an almost unified primary function, they come in various designs, shapes, and with various secondary functions. This is another fascinating aspect of caps. To explore the design of caps, I consulted my friend and colleague, industrial design professor Rajib Adhikary, formerly of the Indiana Institute of Technology in Fort Wayne, Indiana in the U.S.A., and now the founder of KAALO Experience Design https://vimeo.com/77231481.

We asked Professor Adhikary the following questions:

What are the most important elements of design?

Form follows function. The most important elements of design are those that address the five senses of the human being: visual elements, tactile elements, smell, sound, and taste. Of these, visual and tactile are more emphasized than others. [In design] all products [physical or conceptual], interact with the human being in just two ways - physically and mentally. To make a design of a product work, a designer has to satisfy the user functionally and aesthetically. To do this job, the designer exploits these elements of design and satisfies a user's need and much more.

When you design a given product, say a cap for a given bottle, what do you want to know before you start designing the cap?

I would require a proper BRIEF from the client asking me to do the design. In the brief would be stated clearly the following:

1. What is the bottle or container having this cap going to contain? Essentially, the cap plays a big role in the design and image of the product. (For example, is it going to be liquid, semi-liquid, solid, or gas; colored or colorless, etc.)
2. Who is the end user of the product?
3. What materials and processes are going to be involved? How much liberty do I have to choose from the many ways possible to manufacture the caps?
4. Are we going to recycle the caps?
5. Do you want any graphics on the caps? If so, then what kind of image do you want to portray? Do you have any corporate colors?
6. Is there a cost constraint?
7. How many pieces do you want?

8. How much time does the designer have?
9. Do you want this cap to be used in only one specific product or can be used in more than one product now or in the near future?

These are the basic set of questions one would want answered before starting the project.

Where do you start in this process?

The following is the standard design process and each of these phases take varying time periods, depending on the complexity of the project:

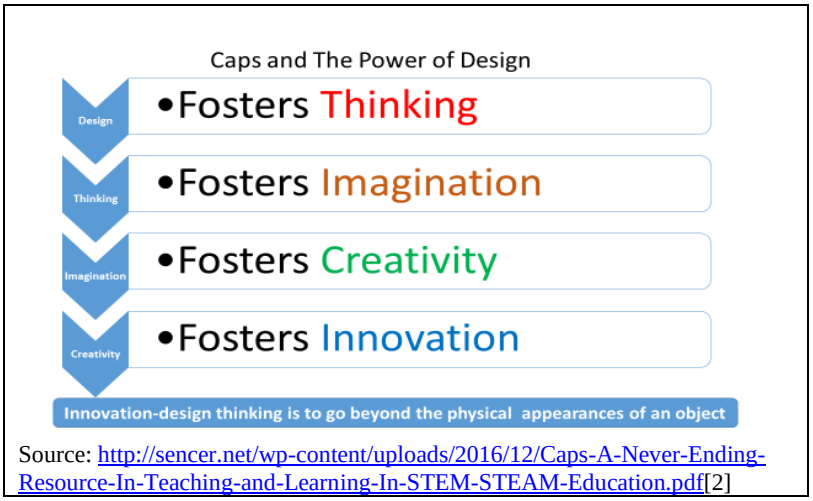
1. Briefing
2. Research and surveys
3. Classification and analysis of the gathered information
4. Identification of the customer's needs, existing concepts, competitive bench marking, etc.
5. Target specification or design criteria is drafted
6. Ideation and conceptualization process
7. Hundreds of sketches and ideas are put down on paper
8. Concepts are then selected and narrowed down in number
9. Details of these concepts are worked upon
10. Sketch physical models and computer-generated models help in this phase. [In the old days, a clay or wood model is made, based on the sketched model]
11. Final concept is selected
12. All ergonomic and human factor aspects are carefully taken care of
13. Final concept is detailed and models representing its forms, etc. are worked out
14. The manufacturing specifications and cost projections are done
15. Final concept graphics, visual elements, packaging and transportation aspects are detailed out
16. Prototype and other working models are tested for function, design, manufacture and aesthetics
17. The product samples are made and pilot samples are tested in the market
18. Depending on the feedback given by the customer, further modification may or may not be required

How do you define the design profession from your perspective as an industrial designer?

I think design is the oldest profession of mankind. Every human being is a designer. Most animals are designers.... very good designers. Personally, I think Mother Nature or God is the greatest industrial designer. If one is looking for perfect designs, no human-made designs are worthy. It is only in nature that one cannot argue with the design in any sense of the word.

Design is nothing but finding a solution for a problem or a need. Many people mistake design to be just the aesthetics of the product, or just the features of the product. Design has a very vast definition, very in-depth and is the result of human behavior, human want, greed, discontent, comfort, need, peer pressure, technology, war, power, money and the list goes on forever. Design rules everybody's lives every single day. We DESIGN our lives. We DESIGN nature to suit us. We DESIGN people and people DESIGN us. We DESIGN technology to satisfy our insatiable hunger for MORE, MORE, MORE AND MORE!

Figure -4- Caps and The Power of Design



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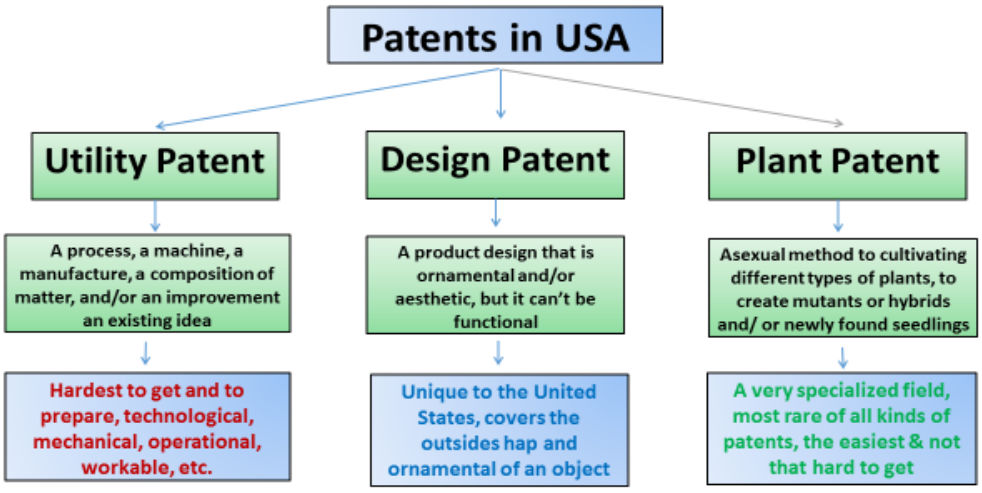
From this interview with Rajib Adhikary we can conclude that the future of industrial design is great at all levels; profession and career, continuous needs, technological innovation, human endeavors, etc. As long as there are human beings and indeed life on Earth, there is design and need for design and designers in various fields and at all levels. Furthermore, and as seen in Figure 4, we can infer from this interview that design has a lasting pedagogical impact on students simply because it fosters thinking, thinking fosters imagination, and imagination fosters creativity, and creativity fosters innovation.

III.8. Activity VIII: Let's Design Caps

To design is to conceive and form an intended plan based on prior experience, knowledge, and available resources, and then to draw a sketch, and execute the plan for intended purposes. With this in mind, for this learning activity, you will need pencils, paper, clay or play-dough, and waxed-paper to complete the assignment. Based on the conversation with the professional industrial designer above, let's re-examine the caps and then try to design our own caps.

1. From your own perspective, examine all the caps in front of you and then select:
   a. The simplest cap. Draw and explain.
   b. The most complex cap. Draw and explain.
   c. The most interesting cap. Draw and explain.
2. Did you make your selection based on functional, structural, material, or other types of criteria?
3. Compare your selection of most simple, complex, and interesting caps with the rest of your group and then the whole class.
4. Compare your explanation of the most simple, complex, and interesting caps with the rest of your group and then the whole class.
5. Using pencils and paper try to design your own most simple, complex, and interesting caps with the rest of your group.
6. Using the clay or the play-dough and waxed-paper, try to transform the drawings of the cap designs you have just completed with pencil and paper into physical form.
7. If you or anyone in your group is skilled in the use of computer graphic software and digital technology, can you transform your drawings of the cap designs you have just completed with pencil and paper into two and three-dimensional digital form.
8. Write down your answers of these questions and end your report by writing one or two paragraphs on what have you learned from this activity.
9. Use all what you have learned from all the activities you have just completed to design your own innovated cap.

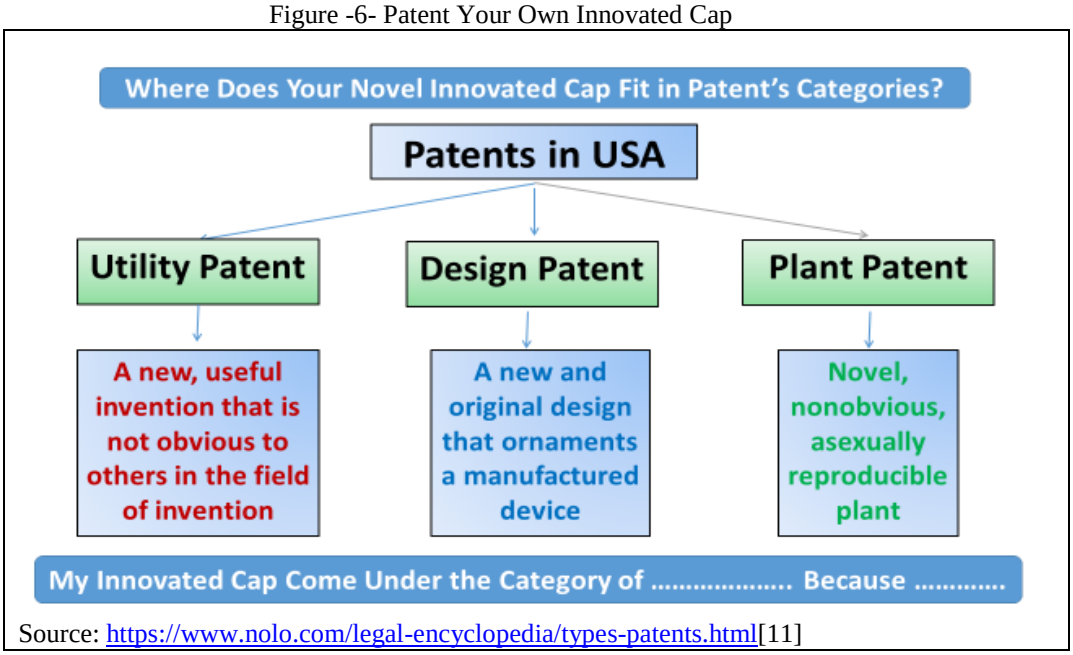
Figure -5- Patents In USA



Source: https://www.nolo.com/legal-encyclopedia/types-patents.html[11]

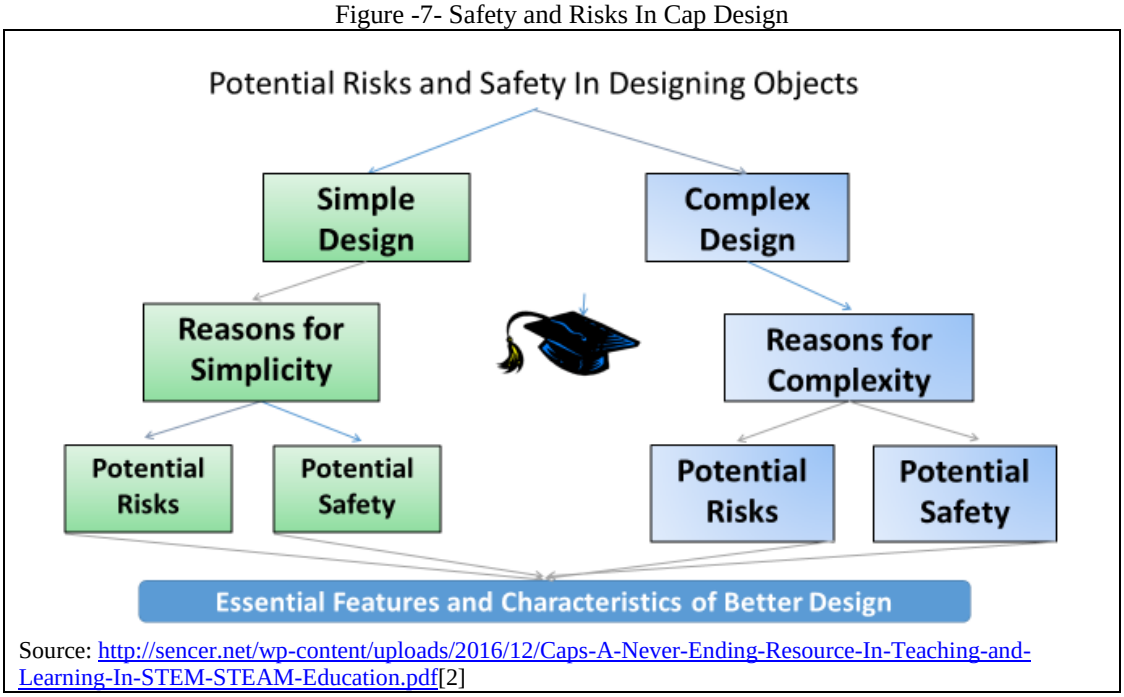
10. Upon completion and getting final approval from your teacher or instructor, study Figure 5, Figure 6, and Figure 7 of some of the different types of patents in the United States of America. According to Attorney Richard Stim (2018) there are three main types of patents in USA. They are utility patents, design patents, and plant patents. Use these three types of patents as a guideline to decide which type of patent you would like to apply for your innovated cap design and why. In addition, Guided with the information in Figures 5, 6, and 7, conduct Internet research to find out how can you apply and where do you need to go to apply for a patent for you're a new invention and design.

Figure -6- Patent Your Own Innovated Cap



Source: https://www.nolo.com/legal-encyclopedia/types-patents.html[11]

Figure -7- Safety and Risks In Cap Design



Source: http://sencer.net/wp-content/uploads/2016/12/Caps-A-Never-Ending-Resource-In-Teaching-and-Learning-In-STEM-STEAM-Education.pdf[2]

III.9. Activity IX: The Power of Imagination – Visualizing and Drawing Images of Your Caps

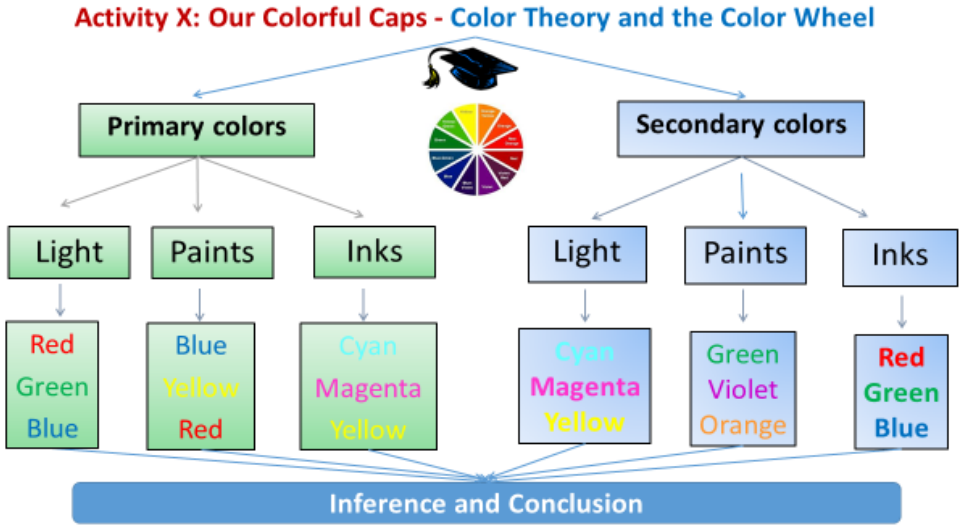
1. Select five caps that differ in color, size, shape, and material.
2. Spend at least 2-3 minutes examining each cap individually using your hands, eyes, and mind. Then form an image in your mind for each cap based on the results of step 2.
3. Draw a picture of the most likely bottle or container that each cap you examined is used for.
4. Share and discuss your final drawing and conclusion with your classmates.
5. Write one or two paragraphs on what have you learned from this activity.

III.9.1. Caps and Beautiful Colors

Throughout the years we have discovered that using caps to introduce topics such as light and color to our college students, whether they are art students, physics students, electronic students, or student-teachers, has been very useful in captivating students' interest, inspiring and motivating them to engage in the learning process and to gain the skills to acquire, make meaning from, and transfer learned knowledge.

The colors we see can be colors of light as in the color of the sunset, or colors of pigment as in the colors of a painting. The colors of light and the colors of paints differ in their nature and in their primary and secondary colors (Figure 8). Primary colors are those colors which cannot be obtained by mixing other colors. Secondary colors are those colors which are produced by mixing two primary colors, while other colors are produced by mixing a variety of combinations and quantities, including (in painting) white and black.

Figure -8-
Primary and Secondary Colors of Light, Inks, and Paints



Source: http://sencer.net/wp-content/uploads/2016/12/Caps-A-Never-Ending-Resource-In-Teaching-and-Learning-In-STEM-STEAM-Education.pdf [2]

III.9.2. Color Theory and the Color Wheel

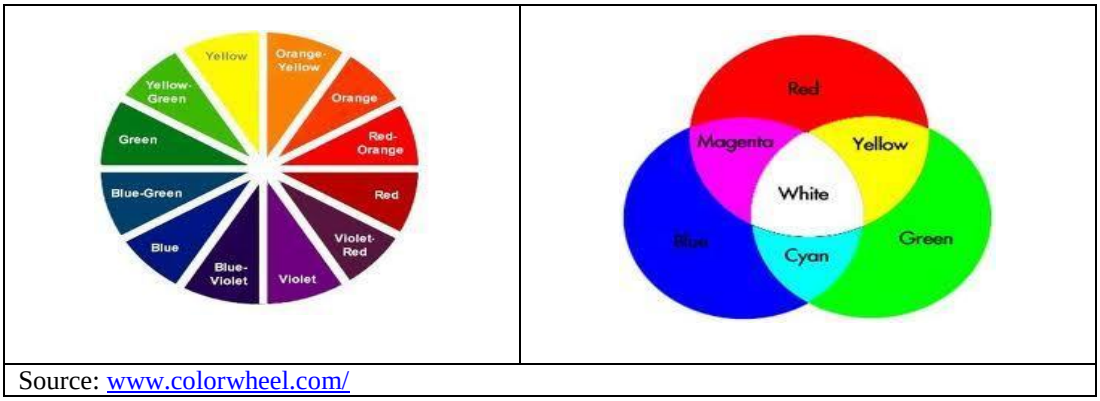
The artist uses a variety of pigments to create exactly the color he or she wants. All the colors, with the exception of white, can be created by mixing the three primary colors; crimson, blue, and yellow. If an artist wants orange, she need only mix crimson and yellow. Mixing blue and crimson produces purple, and mixing yellow and blue creates green. These are called the secondary colors. Using the color wheel below (Figure 9), answer the questions in activity III.9.3. Today, caps can be found in all types of colors, both primary and secondary colors. Because of this, they can be used to illustrate various colors and to reinforce the understanding of color mixing by addition and subtraction among the primary colors.

III.9.3. Identify Our Colorful Caps

1. Using Figure 8 and Figure 9 as a framework, identify the caps that represent the primary paint colors. The primary colors are those hues which cannot be obtained by mixing other colors, such as red, blue and yellow. (They are also called crimson, blue and lemon yellow).
2. What do you think will happen when you mix pairs of primary paint colors? *Mixing pairs of primary colors produces secondary colors.*
3. Identify the caps that represent the secondary colors. Mixing pairs of primary colors produces secondary colors; blue with red makes purple, blue with yellow makes green, and yellow plus red makes orange.
4. Scientists and painters arranged primary and secondary colors on a color wheel. Use caps of different colors to show how primary and secondary colors are arranged on the color wheel.
5. What will happen when two complementary colors (primary color (red) with secondary color (green)) are mixed together? *Mixing two complementary colors will produce a tertiary gray or brown depending on exactly which paints are chosen and in what proportion*.
6. What will happen when you mix two opposite secondary colors with each other? *You will get brown or gray, or a muddy color of one of the secondary colors that you mixed.*
7. What will happen when you mix primary and secondary colors that are next to each other on the color wheel? *You will get a color halfway between the two* [12].

You can repeat the above activity using the color wheel of light instead of the color wheel of pigment**.**

Figure -9-Color Wheel



Source: www.colorwheel.com/

III.10. Activity XI: Caps, Magnets and Electricity

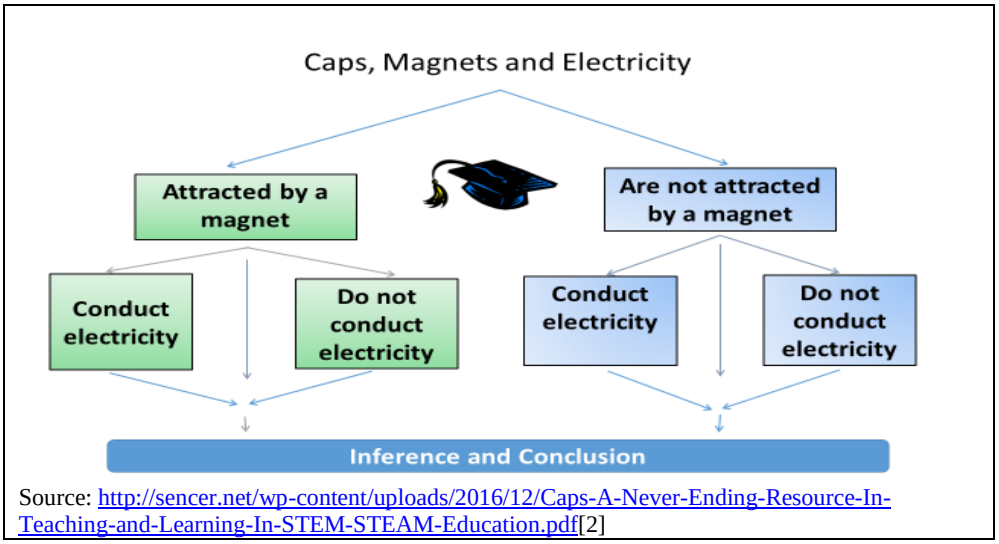
Engage your students in answers the following questions as starting point to explore magnets and electricity using caps around you.

1. From your own perspective, define magnets and electricity. Write down your definitions.
2. Discuss your definitions with the members of your group.
3. As a group, choose the best definition for magnets and for electricity. Write them down.
4. Carefully study all the caps in front of you.
5. Engage in a serious discussion with the members of your group about which of the caps will be attracted by magnets and which will not.
6. Divide the caps into two groups: (a) those, which you think will be attracted by a magnet, and (b) those which you think will not. Explain your predictions.
7. Divide caps in group "a" into those which you think will conduct electricity (group a.i), and those which you think will not conduct electricity (group a.ii). Explain your predictions.
8. Design experiments to examine your predictions in steps 6 and 7 and to discover which ones are the most reasonable.
9. What have you learned from conducting this hands-on activity?

Questions

1. If a cap is attracted to the magnet, then this cap could be made up of one of the following: _____, _____, _____ .
1. List all the types of materials that you think are attracted to magnets: _____, _____, _____ , _____ .
2. List all the types of materials that you think are not attracted to magnets: _____, _____, _____, _____ .
3. If a cap conducts electricity, then this cap could be made up of one of the following: _____, _____, _____ .
4. List all the types of materials that you think conduct electricity: _____, _____, _____, _____ .
5. List all the types of materials that you think do not conduct electricity: _____, _____, _____, _____ .
6. What do you infer about the relationship between magnetism and electricity?

Figure -10- Caps, Magnets and Electricity



Source: http://sencer.net/wp-content/uploads/2016/12/Caps-A-Never-Ending-Resource-In-Teaching-and-Learning-In-STEM-STEAM-Education.pdf[2]

III.11. Activity XI: Density:

Density is the mass (weight) of a substance divided by its volume. Density = mass/volume. If the density of an object is less than the density of water, the object will float. If its density is more than the density of water, then the object sinks.

1. Identify those caps which you think are denser than water and those caps which are less dense than water.
2. Explain the bases of your predictions.
3. Design and conduct experiments to test your predictions.
4. Are more of your caps less dense than water or more dense than water?
5. How do you explain your findings?

III.12. Activity XII: The Use of a Spray Device to Demonstrate Various Scientific Concepts

The Spray Device on various bottles can be used to demonstrate the effect of air pressure on water, the relationship between volume and size, and the relationship between the depth and width of water in a container.

Make sure that each spray device is 100 percent clean. In preparation, divide the class into groups of 3 students, and give each group one spray device and 4 different bottles. One bottle will have a small opening, one will have a wide opening, one bottle will be short and one will be tall. Give students a measuring tape, some newsprint, and regular newspapers.

Procedures:

1. Each group will tape the 11 × 14 piece of paper to the wall, no higher than average shoulder height.
2. Every group must put newspaper on the floor to protect the floor from water.
3. The groups will fill the four bottles with water and add a different color of food coloring to each bottle.
4. Ask all the students: If you place the spray device on a bottle and spray the white paper from a distance of 2 feet, 4 feet, 6 feet and then 8 feet, which bottle will enable you to spray the farthest? Make sure the students don't try this before they give you their predictions.
5. Collect the students' predictions, write them on the board, and discuss them one by one.
6. When there is no more discussion, allow the students to conduct their experiments and to record their observations on the data observation collection sheet.
7. Discuss with the students whether and why their predictions and the actual results differed.
8. Ask the students to try to find explanations for what actually happened.
9. Capitalizing on the students' explanations, introduce the concept of air pressure, the relationship between size and volume, and the relationship between depth and width, etc.

III.13. Activity XIII: Caps, Writing, and Language

1. Write each of the following statements on individual index cards: "I selected it, you drew it", "I drew it, you described it", "I described it, you spoke about it."
2. Divide your students into groups of six students.
3. Ask two students from a group to select two different caps. Write down their reasons for the selection.
4. Ask two more students from the same group to draw the two caps that their two group members selected.
5. Ask two more students from the same group to use the drawing and the reason for selecting the two different caps to write a detailed description.
6. Ask each pair of students to evaluate and provide feedback to the other groups on how they did, using the following criteria:
    a. If I selected my own caps, then I would select _____, _____, _____.
    b. If I drew the selected caps, then I would draw them like this:
    _____
    _____
    _____
    c. If I described the selected caps, this is how I would describe them:
    _____
    _____
    _____ .
    d. If I selected the caps, this is how I would speak of them:
    _____
    _____ .

III.14. Activity XIV: What is the Big Deal About Caps of Pharmacy Medicine Bottles?

1. Divide the students into groups of 4 students. Give each group 2-3 different sizes of caps of pharmacy medicine bottles.
2. Give each group 2-3 caps of medicine bottles from other, different pharmacies as well as a copy of Figure 11.
3. Ask students to study each of the caps from design, structure, and function perspectives.
4. Then, ask each group to compare and contrast between the different types of caps on the various medicine bottles.

III.15. Activity XV: Scientific Investigation and Research Studies:

It is natural for students to ask questions even before they enter elementary schools. But what is not natural for them without been taught is to practice asking the right questions, collect and evaluate the needed data, devise correct solutions to their questions, and effectively communicate the informative solution. Through the study of caps' design, levels of complexities, structure and function these concepts and skills could be introduced, learned, and applied.Through the process, students could easily learn and practice to:

- Ask questions, define problems, and distinguish between questions and problems
- Develop and use models
- Plan and carry out investigation

- Collect, analyze and interpret data
- Use mathematics to search for answers and create models
- Construct explanation and design solution
- Use evidence to engage in informative argument, debate, etc.
- Obtain, evaluate, and communicate information.

Figure -11- Examples of Medicine Bottle Caps

III.16. Activity XVI: Research Study: Recycling Medicine Bottles and Their Caps

In this research study, students engage in conducting research to answer the following question: "How often pharmacies and or pharmaceutical companies do collected and recycle their medicine bottles? In doing so, students engage in both internet research as well as a field research to find out whether and not pharmacies in their communities re-collect and recycle medicine bottle and/or their caps.

1. Ask students to individually visit one or two different pharmacies near their home and to talk with the manager or the pharmacist. Through the conversation try to:
    a. Find out whether or not the pharmacy has a policy for collecting and recycling medicine bottle and or their caps.
    b. If yes, inquire about how long it has been going, how often the customers bring back their empty medicine bottles, and whether they bring them with their caps or without the caps.
    c. If not, inquire about the reason for not having a policy and procedure for things such as this.
2. Upon completing their field research, ask the students, individually, to conduct internet or library research to find out if there is any pharmacy and or pharmaceutical company that collects and recycles their empty medicine bottles or their caps.
3. Have each student write a research paper describing their field and library or internet studies including procedures, findings, analysis, conclusion, and inferences, and concluding with a recommendation.
4. Have each student write a letter to the manager or the pharmacist of the pharmacies that they visited to share their findings. Include in the letter an informative rationale of why recycling is a good strategies for both good business practice, and for environmental sustainability.

III.17. Activity XVII: Do You Wonder What to Do with Your Bottle Pills Caps that Pharmacies Use to Package Prescriptions?

So often, the bottle pills caps, tops, and lids are made from different type of plastic, mixed type of plastic, and or different thickness and toughness. For example, plastic caps are typically made from a type of plastic called polypropylene or plastic #5 and letter PP underneath that. This type of plastic is usually found in sturdy things, like garden rakes, brooms, and ice scrapers. On the other hand, the plastic bottles they accompany are usually made from a different kind of plastic called polyethylene terepthalate, or form # 1 and PET (some are made from #2). These two types of plastic melt at different temperatures during the recycling process and therefore requiring special processing.

So far, however, beyond their main designated function, (and caps which have significant pedagogical and educational uses, as we hope you now realize), no one has been able to devise a means of obtaining monetary value for re-using pill bottle caps. Indeed, as Mikkelson (2015) stated:

> Plastic bottle caps have no inherent monetary value. Unlike aluminum cans (and the metal tabs attached to them), they aren't worth anything as raw material because such caps are the wrong form of plastic to be recycled. There is therefore virtually no market for used plastic bottle tops. But even though the collected bottle caps weren't worth anything in and of themselves, and no large corporation was trumpeting its involvement in the rumored "Save a kid by saving your bottle caps" program, people's desire to help blinded them to those realities. [13,¶. 6]

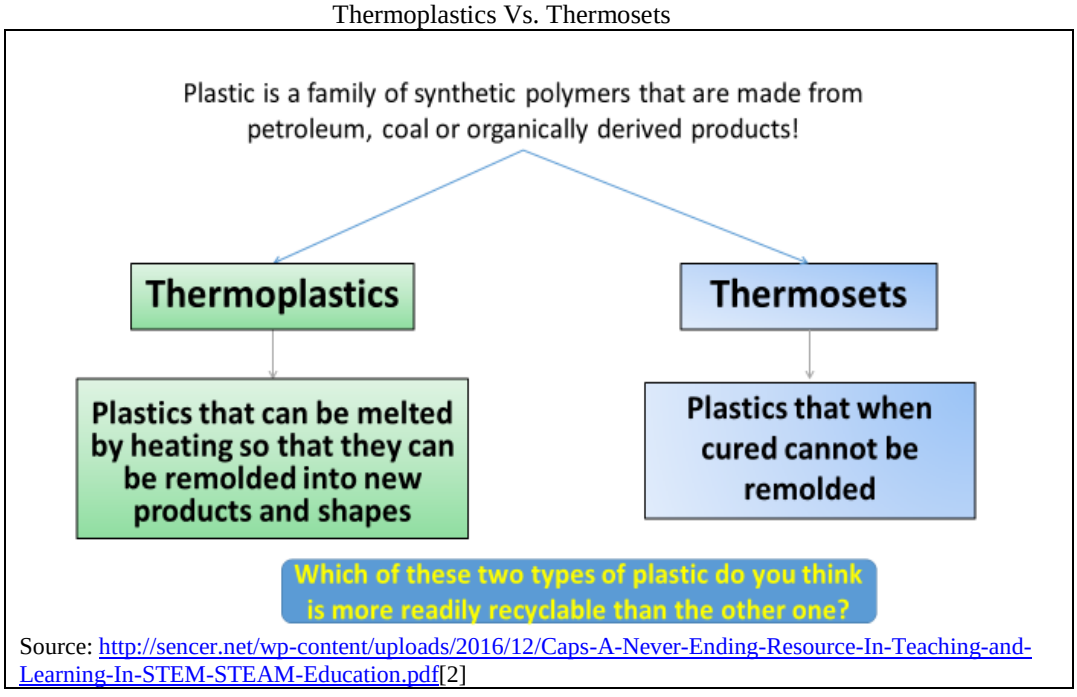
The story with plastic bottles themselves, including medicine bottles, is totally different. According to RecycleScene (2016):

> Take a look at the bottom of your plastic medicine or prescription bottle and see if there is a number 5**,** sometimes with the letters PP below it. The PP stands for polypropylene. Number 5 plastics are very common, including many types of yogurt or hummus tubs, and other things you regularly bring home from the grocery store. [14, ¶. 2]

If the medicine bottle is a translucent, amber color, the number most likely will a 5 which means it is made of polypropylene, and thus it is definitely recyclable. The problem however it is not its type of the plastic, but the problem is their physical size as noted by David Cornell, technical director of the Washington, D.C.-based Association of Postconsumer Plastic Recyclers [15]. This is simply because:

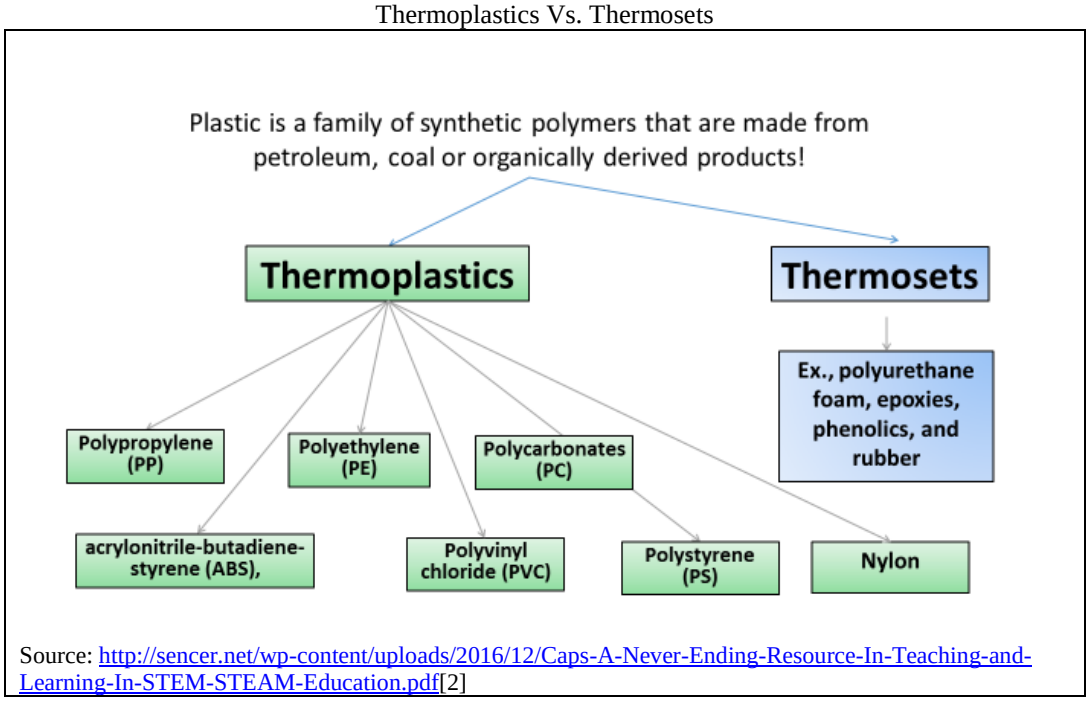
> Many local municipalities with curbside pickup programs sort their recyclables with a screening device called a trommel, which has small holes used to remove unwanted debris. Bottles, cans and containers as large as water bottles remain in the trommel for proper recycling, while broken glass, rocks and other items fall through the holes and are sent to the landfill. "Small bottles have a nasty habit of looking like broken glass and scraps to a trommel," Cornell says. "For this reason, recycling pill vials in a curbside program shouldn't be done unless you can find out if your system can handle the small size. [15, ¶. 3,4]

Figure -12-A
Thermoplastics Vs. Thermosets



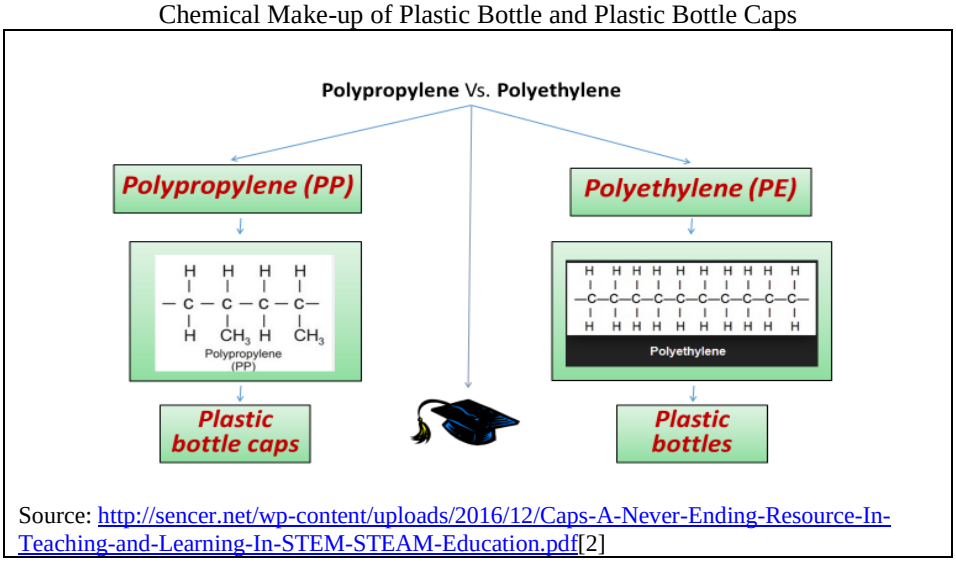
Source: http://sencer.net/wp-content/uploads/2016/12/Caps-A-Never-Ending-Resource-In-Teaching-and-Learning-In-STEM-STEAM-Education.pdf[2]

Figure -12-B
Thermoplastics Vs. Thermosets



Source: http://sencer.net/wp-content/uploads/2016/12/Caps-A-Never-Ending-Resource-In-Teaching-and-Learning-In-STEM-STEAM-Education.pdf[2]

Figure -13-
Chemical Make-up of Plastic Bottle and Plastic Bottle Caps



Source: http://sencer.net/wp-content/uploads/2016/12/Caps-A-Never-Ending-Resource-In-Teaching-and-Learning-In-STEM-STEAM-Education.pdf[2]

III.18. Activity XVIII: Caps and The Power of Imagination:

It has been stated that "to be imaginative necessarily involves mastery of certain branches of understanding in the areas in question" [9, p. 145]. Imagination is the mental ability to bring previous and existing experience to live and to use them to create a mental image, concept, or an idea of that which is not real or present. In other words, the mental ability to deal creatively with reality by creating something new. Barrow and Milburn (1990) who perceive imagination as something that has commonality with creativity, and to lesser extent with intelligence and critical thinking, see it to serve as "an emotively positive term that suggests a capacity to be inventive, unusual, or productive of ideas, as well as inspirational visitation" [9, p. 145]. It is because of this type of thought that we have designed to include the following activity of Caps and The Power of Imagination.

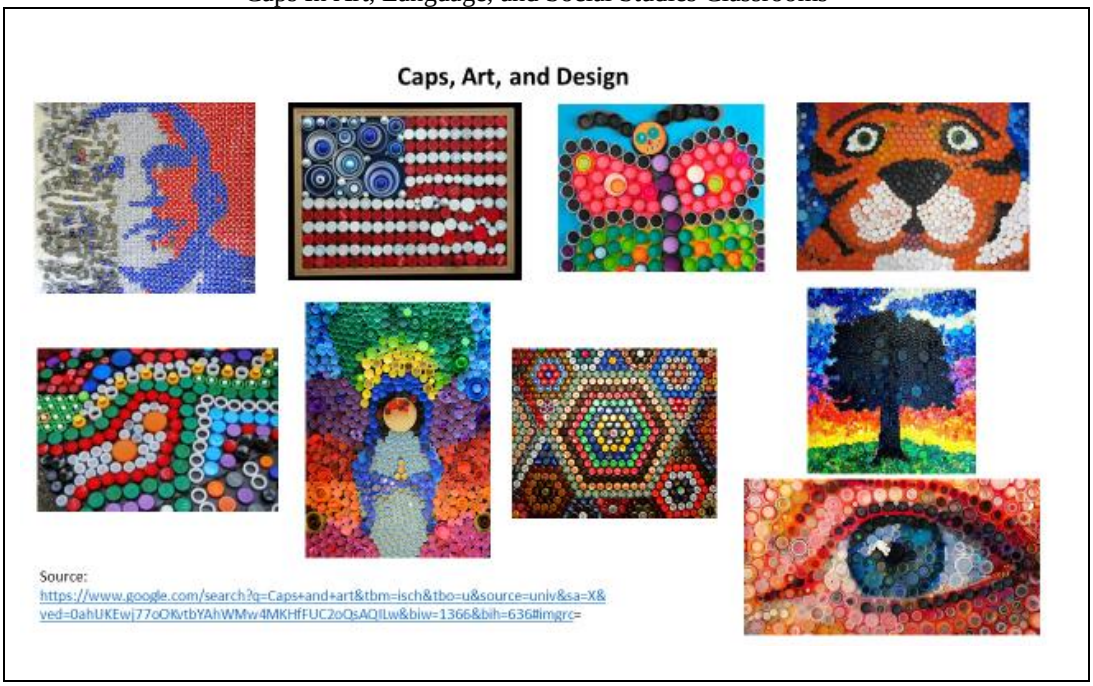
1. Divide the students into groups of three students. Give the members of each group five different caps.
2. Ask the members of each group to examine each one of the five caps.

3. Then, ask them to try to imagine, write down, and draw the type of an object (bottle or container, etc.) that each cap is designed for.
4. Ask the members of each group to explain how and why they imagine what they did.
5. When each groups fish the tasks, allow the students to go around and to share their outcomes with each other.
6. Finally, discuss in the class the important and the power of the imagination in human lives.

IV. Caps In Art, Language, and Social Studies Classrooms

Students learn better when they are able to make a real connection with the learning materials. Making connections can help make the learning experience for students academically comprehensive, engaging, insightful, and inspirational not only in the sciences but also in non-science disciplines such as the arts, language, and social studies. Through the use of caps, students can learn and discover that many of the arts' skills are eminently learnable and don't depend totally on innate talent.

Figure -14-
Caps In Art, Language, and Social Studies Classrooms



Divide the class into groups of two students to work together. Using caps and only caps, challenge each group of the students to:

1. Colors of the flag of their country, state, country, city, and or the colors of the school. Then use the collected colored caps to physically create the selected flag. In addition, calculate the percentage of the selected colors to each other in a given selected flag. Finally describe in writing and in graphic form what you have done and learned.
2. repeat step one using your favorite:
    a. Word, such as Thank You, Friend, Mother, Father, etc.
    b. Map of a country
    c. Hero
    d. President in the world
    e. Sports person
    f. Living form
    g. Mountain, river, or sea
    h. Flower.
3. Identify the challenges you encountered to complete this activity and how you overcame these identified challenges.

4. Finally, each group to write an article that is intended to be published in a local newspaper about the use of caps in arts and how this can be part of education, learning and recycling and promoting sustainable practice in our fragile ecosystem.

V. PEDAGOGICAL REFLECTION AND FINAL REMARK

Lack of material resources to introduce and teach STEM and STEAM topics has been one of the things that school teachers have considered as a barrier preventing them from effectively teaching STEM topics at the K-12 level. However, while resources are essential for effective teaching and learning, resources don't have to be expensive or special to be used in teaching. Many familiar and easily obtainable materials can be used as good resources in introducing and teaching STEM topics. Indeed, any object you encounter, regardless whether it is natural or human made, has science, math, design, engineering, arts, and numerous other elements and concepts implied in its design, structure, and composition. As such, it can be used to introduce, teach and learn STEM topics. One of the many effective ways to motivate students to be actively engaged in their own learning processes is to use relevant, familiar, and practical objects in ways that they have never thought of before. Bottle caps and jar lids are among these types of objects. They are relevant, familiar, practical, are really quite fascinating objects. They are made of a variety of materials and come in different, sizes, shapes, designs and levels of design complexity, functions, colors, and patterns. In addition, while the main function is the same for almost all types of caps, they are engineeringed and designed to use various mechanisms to achieve that function. Because of this, there is almost no subject or concept in STEM/STEAM education that cannot be introduced and or taught using caps. For example, in designing a particular cap, STEM concepts are repeatedly involved, from physical and mathematical concepts to graphic design, selecting the right construction materials, choosing the correct shape, appealing to aesthetics (the best color, luster and form for visual appeal), to name a few. All these elements have to fit and complement each other to achieve the main purpose and function of a given cap, and also communicate any hidden message the designer wishes to communicate to consumers and users of the product. In addition, all these elements must be described and produced in written form correctly and in detail for all those who are involved in the processes, from the designers to the manufacturers, and from the decision makers to sales reps, to name a few. Because of this, for teachers and educators ***caps*** can have a multitude of educational and pedagogical uses that help create learning pathways which work with a variety of student interests and needs and help remove potential barriers that deny many learners equal access to excellence and success in STEM and other fields. There is no doubt that using caps pedagogically in the learning process can help free the imagination, ignite creative thought, and motivate engagement in the learning process among many students from a wide variety of backgrounds!

VI. ACKNOWLEDGEMENTS

We would like to thank all the instructors, teachers, and student-teachers who attended one of our workshops or presentations either in national conferences or in the classroom setting. We also would like those teachers and instructors who shared with us their own experience in conducting some of these activities in their own classrooms. Finally, we would like to thank *Science Education For New and Civic Engagements and Responsivities (SENCER)* Midwest Region for its recognition of our cap project by awarding us one of the 2016 Midwest Implementation SENCER Awards.

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