Teacher Toolkit - Color Addition and Subtraction

Objectives:

1. To identify the three primary colors of light and describe the result of mixing these light colors in equal and unequal intensity.
2. To describe the significance of complementary colors, identify the three sets of complementary colors and use complementary colors and the principle of color subtraction to explain why an object appears the color that it does when viewed under white light.
3. To predict the color appearance of an object when viewed under various combinations of red, blue, and green spotlights.
4. To identify the three primary pigments and the light color that each absorbs and to use this knowledge to predict the light colors that such pigments would absorb or reflect.
5. To use the principle of color subtraction to predict the light color(s) absorbed and transmitted by a color filter.

Readings:

The Physics Classroom Tutorial, Light Waves and Color Chapter, Lesson 2
http://www.physicsclassroom.com/class/light/Lesson-2/The-Electromagnetic-and-Visible-Spectra

Interactive Simulations:

1. RGB Color Addition http://www.physicsclassroom.com/Physics-Interactives/Light-and-Color/RGB-Color-Addition
   This simulation focuses on the mixing of red, green, and blue-colored lights on a screen. You can adjust the light intensity or remove one of the colors and see what happens.
2. Painting with CMY http://www.physicsclassroom.com/Physics-Interactives/Light-and-Color/Painting-with-CMY
   This Interactive and accompanying classroom exercise provides an exceptional introduction to how the primary colors of paints can be used to subtract primary colors of light and produce the intended appearance.
3. Colored Shadows http://www.physicsclassroom.com/Physics-Interactives/Light-and-Color/Colored-Shadows/Colored-Shadows-Interactive
   In this interactive, learners explore how colored lights become blocked and result in the formation of a "colored shadow' on the screen. You can turn on 3 different lights to vary the resultant shadows.
4. Color Separation http://micro.magnet.fsu.edu/primer/java/primarycolors/colorseparation/index.html
   This tutorial explores how individual subtractive primary colors (yellow, cyan, magenta) can be separated from a full-color photograph, then reassembled to create the original image.
5. Colored Filters http://www.physicsclassroom.com/Physics-Interactives/Light-and-Color/Color-Filters/Color-Filters-Interactive
   Learners explore the affect of colored filters upon primary colors of light with this variable-rich environment.

Hands-On Lessons and Activities

1. It's a Colorful Life http://www.sci-ed-ga.org/its-a-colorful-life
   This multi-day unit, sponsored by General Dynamics, was designed as a set of 6 interlinked experiments to explore how colors are formed by light absorption and emission. Detailed lesson plans, student activity guides, and background information are provided.

Video and Animation:

1. Veritasium: Persistence of Vision https://www.youtube.com/watch?v=bcstc1oczcQ
   In this short video, physicist Derek Muller looks at a plastic ball with three flashing LED's inside (red, green, and blue). Turn the ball on and it appears to be a light violet color. But twirl it around in a circle and you can clearly see the 3 primary colors of light appear individually.
2. Primary Colors of Light and Pigment
   http://www.pbslearningmedia.org/resource/lsps07.sci.phys.energy.lightpigment/primary-colors-of-light-and-pigments/
   This resource combines video with animation to shed light on the difference between the primary colors of light vs. the primary colors of paint pigment.
3. Physics Girl: Does This Look White to You? https://www.youtube.com/watch?v=uNOKWoDtbSk\
   This episode of "Physics Girl" does a nice job of explaining how light-sensitive cone receptors in the human retina work to perceive color.
4. Discovery: Colours of Light https://www.youtube.com/watch?v=Hbxy1W9O_Wk&nohtml5=False

   This 4-minute video takes a closer look at color, to go beyond the primary RGB colors of light.

Labs and Investigations:
The Physics Classroom, The Laboratory, Light and Color Section

1. Color Addition
2. Taking Away from RGB
3. Painting with CMY
4. Filtering Away

Link: http://www.physicsclassroom.com/lab#light

Demonstration Ideas:

1. Colored Light Shadow-Additive Light Mixture https://www.youtube.com/watch?v=eKj1EwJ7THU
   Pennsylvania science teacher Bruce Yeany brings us a nicely-shot video that can be used as a warm-up or as a low-cost classroom exploration using 3 LED lights to demonstrate colored shadows.
2. Exploratorium: The Three Little Pigments http://www.exploratorium.edu/snacks/three-little-pigments
   Here's an inexpensive way to investigate how light and color interact by overlaying cyan, magenta, yellow (the primary pigments), and black transparencies.

Minds On Physics Internet Modules: http://www.physicsclassroom.com/mop

The Minds On Physics Internet Modules are a collection of interactive questioning modules that target a student's conceptual understanding. Each question is accompanied by question-specific and detailed help.

1. Light and Color Module
   Ass't LC3 - Primary Colors of Light
   Ass't LC4 - Complementary Colors of Light
   Ass't LC5 - Color Subtraction
   Ass't LC6 - Pigments
   Ass't LC7 - Pigments and Color Subtraction
   Ass't LC8 - Filters
   Ass't LC9 - Shadows

Conceptual Building Exercises: http://www.physicsclassroom.com/curriculum/light

The Curriculum Corner, Light and Color Chapter

1. Reflection, Transmission and Color
2. Color Addition and Subtraction
3. Viewed in Another Light
4. Pigments and Paints
5. Shadows

Science Reasoning Activities:

1. Shedding Light on Light Bulbs
   Link: http://www.physicsclassroom.com/getattachment/reasoning/light/src36.pdf

Real Life Connections:

1. How Chameleons Really Change Color https://www.youtube.com/watch?v=Kp9W-_W8rCM
   This beautifully filmed video from KQED uses ultra-HD and clips from electron microscopes to show what's really going on when chameleons change color.
2. Digital Imaging-New Opportunities for Microscopy http://www.microscopyu.com/articles/digitalimaging/drentdigital.html
   This article explores how newer technologies are applied to image capture.
3. Human Vision and Color Perception http://micro.magnet.fsu.edu/primer/lightandcolor/humanvisionintro.html
   For students wanting to take a deeper dive into the human eye and its unique mechanisms for perceiving color, here's a great tutorial from Florida State University's Optical Microscopy Primer on light and color.

Common Misconceptions **See the Complete Toolkit for More Details.**

1. The Color is in the Light
2. The Importance of Nouns
3. Physics vs. Art

Standards:

A. Next Generation Science Standards (NGSS)
Performance Expectations - Physical Science: Waves - Electromagnetic Radiation MS-PS4-2
Disciplinary Core Ideas – Middle School: Electromagnetic Radiation MS-PS4.B.1 and MS-PS4.B.3
Disciplinary Core Idea: Middle School Life Science: Information Processing MS-LS1.D.1
Crosscutting Concepts: High School - Structure and Function Middle School - Patterns
Science and Engineering Practices
Developing and Using Models – High School
Obtaining, Evaluating, and Communicating Information – High School
Constructing Explanations – High School