Easily Transportable User-Friendly Table-top Color Science Laboratory

Abbey Helfer, Gregory R. Savich, Samuel Lamendola, Hayden Binicewicz,
Alyssa Almekinder, Landon Stone, Susan Noonan, Alexis Vogt
Optical Systems Technology, Engineering Technologies, Monroe Community College

SPIE.

Optical Systems Technology
MONROE COMMUNITY COLLEGE

INTRODUCTION

A transportable color science laboratory was developed, refined, and deployed to over 13,100 participants. Laboratory visitors are illuminated to the hidden optical physics behind white light and color generation as experienced in the real-world. The laboratory is optimized for public STEM outreach at every age while maintaining a primary focus on inspiring STEM interest in student-aged participants. Narrative emphasis reflects a focus on science that affects everyday life rather than driving interest in STEM career pathways.

Visitors to the laboratory explore the hidden color found within white light through self-led exploration of hands-on demonstrations and guided learning via trained optics students and staff. Participants leave with a deeper understanding of how the sun, light bulbs, and electronic displays create the color present in our daily lives.

Maximizing Outreach Impact

To increase youth interest in STEM and STEM careers, the approach to outreach should abide by the following principles:

- Focus on teaching science and not promoting careers
- Occur out of students' classrooms
- Relate to real-life applications and societal impacts
- Include hands-on, self-led, and engaging demonstrations
- Include interaction with college-level mentors and professionals

Laboratory Motivations

To maximize learning impact, the classroom should:

- Teach real, approachable optical physics
- Illuminate an aspect of daily life that is often overlooked or otherwise unseen
- Facilitate interactive, hands-on learning
- Expose participants to professional optical components

Demonstration Development

Hands-on demos were optimized for all-age delivery and maximum impact:

- Constructed from optical components used in research and industry laboratories
  - Public sees into the world of an optical scientist/engineer
  - Demos are robust and safely transportable
- Safe for touch and interaction by people of all ages
  - No electrical, blinding, or sharps hazards present
  - Intuitive optomechanical design and use

Laboratory Concept

Color Science was chosen as the topic for the classroom, and a teaching narrative was developed and refined.

- *Operating Assumption:* The average person does not understand how color manifests via the sun and how digital displays are designed to directly address the human visual system.

METHODS

Laboratory Learning Outcomes

Not all white light is the same; white light can contain all colors of the rainbow or as few as three colors.

Glass in the right shape can be used to split thermally generated white light into all colors of the rainbow.

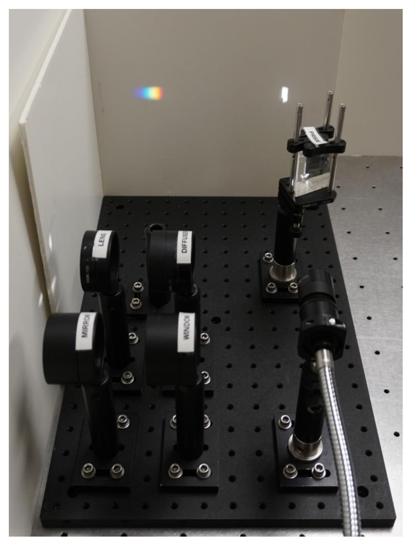
Phone screens, computer screens, televisions, and other digital displays produce white light and color via RGB color mixing.

Different light bulbs make white light in different ways; the way each style bulb makes white light affects its electrical efficiency.

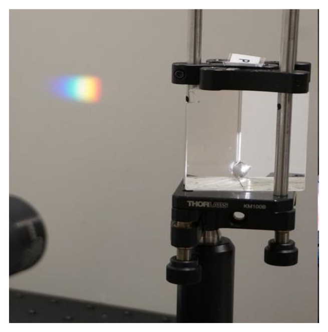
Switching from obsolete light bulb styles to state-of-the-art LED light bulbs reduces our energy consumption and saves money.

How do you Make a Rainbow?

- Optical Dispersion via a Prism



Optomechanical Build



Hands-on Component:
Learners add one of five provided optical components to the system.

Learners rotate each inserted element to search for the appearance of the rainbow pattern.

Learners can hold and manually manipulate placement of each element.

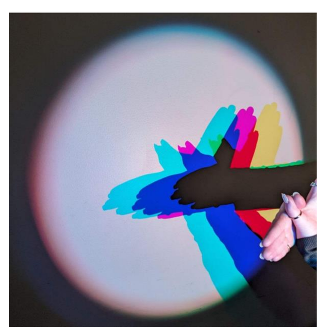
Experiment Outcome
A prism can be used to split white light into the colors it contains!

White light can be made of all colors of the rainbow added together!

How do Digital Displays Make Color?

- Red Green Blue (RGB) Color Mixing

Optomechanical Build



Hands-on Component:
Learners use knobs to change the brightness of LED light sources of different colors: red, green, and blue.

When the learners set all three LEDs to full brightness, white light appears.

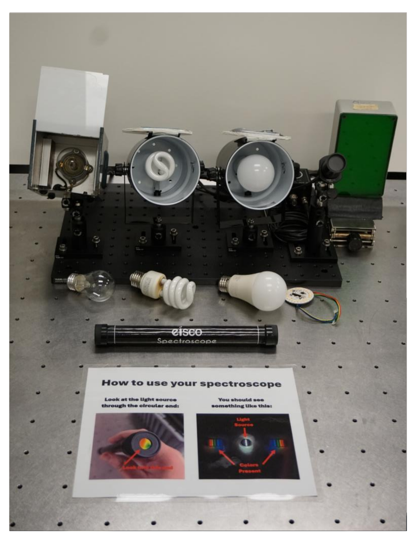
As learners change the brightnesses of each LED, different colors appear.

Experiment Outcome
White light can contain just three colors: red, green and blue!

You can also use red, green, and blue to make almost any color!

How do Light Bulbs Make White Light?

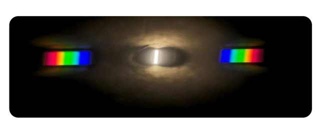
- Spectroscopy of White Light Sources



Optomechanical Build

Incandescent Light Bulb

Fluorescent Light Bulb



White LED Light Bulb

Hands-on Component:
Learners view the spectra of various laboratory light sources and consumer white light bulbs with a spectroscope.

As each light source is activated, the spectra are compared and contrasted.

Differences in light bulb construction and heat generation is demonstrated.

Experiment Outcome
Different light bulbs make white light in different ways!

The energy efficiency of a light bulb type is directly related to how it makes light!

RESULTS

Over 13,100 members of the public have been reached by the color science laboratory since October of 2023. Participants encompass a diverse set of backgrounds, life experiences, and ages ranging from infants to senior citizens. Attendees come from both Upstate New York and across the world.

Public Reach to Date

	Attendance
Rochester STEAM Fest	►200
Rochester Maker Faire	►500
Community Engagement	►100
Dual Enrollment Classes	►300
RMSC Roc the Eclipse Festival	►12,000

Total Attendance Exceeds 13,100

CONCLUSIONS

A Color Science laboratory was developed and deployed to over 13,100 members of the public from Upstate New York and across the world. Through hands-on demonstrations and guided instruction, participants learn something unexpected about how light affects their daily lives and leave with a deeper understanding of the hidden world of white light and color.

REFERENCES

1. Vennix, J., den Brok, P., Taconis, R., "Do outreach activities in secondary STEM education motivate students and improve their attitudes towards STEM?," International Journal of Science Education 40(11), 1263–1283 (2018).

2. Zhou, B., "Effectiveness of a pre-college STEM outreach program," Journal of Higher Education Outreach and Engagement 24(3), 61-72 (2020).

3. Azman, H. H., Maniyam, M. N., Yaacob, N. S., Nawawi, N. M., Samah, N. N., Alias, R., Hassan, K. B., Kamaruddin, H. H., Khalid, R. M., et al., "STEM outreach program: An evaluation on students' perspective towards stem engagement via school-university mentoring partnership," Journal of Physics: Conference Series 1882, 012148 (2021).

4. Kruschwitz, J. D. T., Field Guide to Colorimetry and Fundamental Color Modeling, SPIE Press, Bellingham, WA (2018).

The authors wish to acknowledge support provided by: Robert Parada, Mike Pomerantz, Brian Lake, Bob Lasch, Esther Dykstra, Tobey Palmer, and Trevor O'Loughlin.