

# Teaching Students about White Balance and Color Correction using Digital Photography

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*Editor's Note: To view the photos in color go to:*  
<http://www.igaea.org/Images/Waite/>

## Introduction

Today's consumer expects good color reproductions. Yellow people, green skies, and blue foliage are not acceptable in today's color-charged world. Southworth and Leyda (1998) describe some of the factors that cause a color reproduction to be "good" in the eyes of the beholder as the following:

- The contrast must be correct.
- The color hues must be accurate.
- Memory colors must be accurate.
- The color balance must look natural.
- Gray balance should be accurate and look normal.

"Good" reproductions are dependent upon the light source used to illuminate the subject, the film or digital camera settings, the calibration of the computer, scanner, and monitor, skillful use of image editing software, and appropriate color separation processes. If the light used to illuminate the original scene is not white, the colors in the photographic image will be skewed toward the predominant color produced by the light source. Such photographs are incorrectly white balanced and all the colors in the image will be off balance.

The impact of the light source on a color image has traditionally been difficult to explain to graphic communications students because film had to be developed before feedback could be obtained. However, the advent of the digital camera now makes it possible to not only photographically capture correct colors but to also purposefully capture incorrect colors. In addition, feedback to students is almost immediate. Since the quality and accuracy of the original photograph affect all subsequent processes, this paper will describe a demonstration activity that teaches students the why and how of capturing images that closely approximate the original scene, the importance of calibrating their monitors, and the use of image editing software to correct images that have been incorrectly captured.

In addition to explaining the technology involved in capturing correctly white-balanced color images and subsequent adjustments that must be made, setting up a demonstration in which illuminant and camera settings result in both correctly and incorrectly white-balanced reproductions will help students to understand the impact of light on a reproduction. In addition, the use of tools, such as the GretagMacbeth Color Checker, makes it easy to show students how to fix incorrectly white balanced images using Photoshop®. This paper includes an Equipment, Materials and Facilities List as well as step-by-step instructions for such a shoot. These instructions have been successfully employed in several college-level classes and at the 2004 International Graphic Arts Education Association Conference (IGAEA, 2004).

## Theoretical Background

Southworth and Leyda (1998) summarize the attributes of a "good" color reproduction—"Clean and bright is always right. Dull and gray is not the way. People should never be blue or green." Students must understand that these statements are easy to say, but hard to put into practice. These challenges are magnified in the classroom due to the variety of images on which students work and the often-questionable calibration of equipment.

Students must first understand that there are four distinct areas that have the potential to affect the color reproduction of an image. These processes are:

- (a) the original image must be captured photographically in such a way that the resultant film or file contains colors closely approximating the original scene;
- (b) the image must be appropriately transferred to a properly calibrated computer workstation using, if necessary, a well-characterized color scanner;
- (c) image editing software must be properly used to correct or "tweak" the colors in the image; and
- (d) either closed-loop or color-managed color separation techniques must be employed to effectively prepare the image to accommodate the specific attributes of the paper, ink, printing process, and press that will be used to reproduce the image.

These processes are difficult, if not impossible, for students to understand without concrete hands-on exercises.

## Capturing Photographic Images

Leading up to the demonstration, it is imperative that students understand the physics of light as well as the concepts of absorption and reflection.

As a unit-organizing concept, it is effective to explain that the root words that were combined to create the word “photography” are photos (“light” in Greek) and graphein (“to write” in Latin). Thus, photography is “writing with light” and students must understand the dramatic effect that light has on colorful objects. In particular, an object or scene will appear differently when illuminated with varying light sources. Students must be aware that people seldom notice the effect of a light source on an image. Humans have poor color memory because our brains accommodate for varying illuminations.

Teachers should emphasize that illuminating light strikes the object being viewed or photographed. Some of the illuminating light, known as incident light, is absorbed by the pigments that are inherent in an object. The unabsorbed light is reflected to the viewer of the scene and/or to the camera. The color content of a photographic image, therefore, depends upon the incident light as well as the absorptive and reflective characteristics of the object(s) being captured.

Although the nature of light absorption and reflection by pigments is well known and can be easily taught, the impact of the light source on a photograph is more difficult to explain to students. Teachers need to begin by explaining the impact of white light on a scene. Physically, the only true white light source is the sun. Unfortunately,

sunlight is only truly white when it is unobstructed by the earth’s atmosphere, clouds, or air pollution. Therefore, white light is extremely rare.

If white light, which contains equal amounts of red, green, and blue waves, were to strike a yellow apple, then the blue light would be absorbed by the apple and the red and green waves would be reflected to the viewer’s eye. The human viewer’s brain would combine the red and green waves into yellow (see Figure 1).

Most photographs are captured using light that does not contain equal amounts of red, green, and blue. In particular, artificial light sources, i.e., those created by humans, seldom approximate white and can range from very yellow to blue-green. For example, if an object contains yellow pigment, the yellow will appear muted in blue-green fluorescent artificial light. Similarly, blue pigments will be desaturated if viewed in smoggy, natural sunlight. The human visual system compensates for these variations, but cameras may not.

If the color of the incident light is known, then the photographer can compensate for it during image capture. Begin by teaching students that the color of a light source is measured by its temperature in degrees Kelvin, or °K. By way of explanation, zero degrees Kelvin equals -273° Celsius and is the lowest possible temperature (NASA, 1999). A standard “object,” known as a black-body, is heated to a given degree Kelvin and the color the object glows is noted by using a color temperature meter. Lower Kelvin temperatures, such as 2400°K are red; higher temperatures, such as 9300°K, are blue. Direct sunlight is 4874° K (X-Rite, 1998).

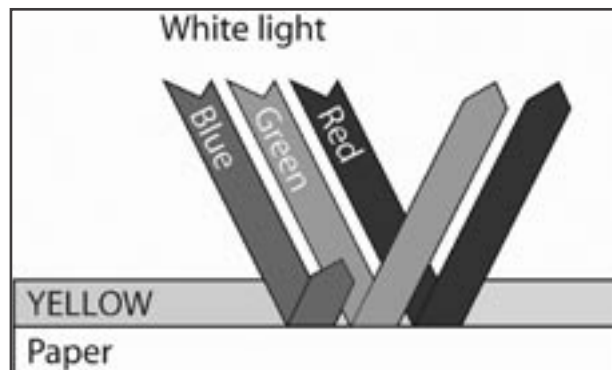


Figure 1

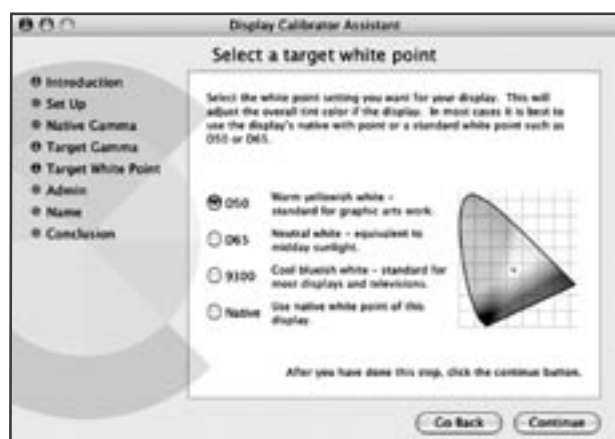


Figure 2

The Commission Internationale d’Eclairage (CIE) used degrees Kelvin in 1931 to specify a series of standard light sources called Illuminants A, B, and C (X-Rite, 1998).

- Illuminant A is 2856°K and represents incandescent lighting as emitted by standard screw-in tungsten light bulbs.
- Illuminant B represents direct sunlight and is 4874°K.
- Illuminant C is 6774°K and represents indirect sunlight such as that known as “northern exposure.”

In due course, the CIE refined its color temperature standards to include two specifications for “daylight.” These daylight standards are used when viewing color images in printing plants and when calibrating computer monitors (X-Rite, 1998).

- D50 refers to 5000°K and is the standard for graphic arts viewing and monitors in the United States (see Figure 2).
- D65 refers to 6500°K and is often used as the standard for graphic arts viewing and monitors in Europe and Asia.

CIE standards were used by film manufacturers to produce films that compensated for the characteristics of light sources. The photographer was required to purchase the appropriate film to match the characteristics of the illuminant to be used during image capture. In particular, film manufacturers sold “daylight” and “tungsten” balanced films.

## Use of Filters

Students need to know how photographers can compensate for a mismatch between a color-balanced film and the actual light source through the use of filters. If a photographer captures an image illuminated with tungsten light (Illuminant A) using tungsten-balanced film, the captured image will be properly white balanced because the film was designed to compensate for the lack of blue in yellowish tungsten light. Similarly, a photo taken outside with daylight film would contain the appropriate colors because the film was manufactured with the expectation that white light (i.e., an equal combination of red, green, and blue waves) would be used during exposure.

However, if daylight film is used indoors, the photograph would be too yellow because the film is not designed to compensate for the yellowness of the illumination. Similarly, if tungsten-balanced film is outdoors,

the image would be blue-green because the film is designed to compensate for the lack of blue-green light in tungsten illumination. Of course, both of these scenarios assume that the actual light source is the exact same color temperature as that for which the film was designed. This is a huge assumption and seldom occurs.

Photographers use a color temperature meter to determine the exact color of the illuminant and then install one of a series of filters over their camera lenses to, in effect, change the color of the light source to that for which the film was made (Hirsch, 1993).

Before the advent of digital cameras, the effect of any combination of light source, film, and filter could not be observed until after the film had been developed. Thus, properly capturing color images required a great deal of skill on the part of the photographer. Such skill took time to develop and made it difficult to explain the complex relationship of light source/film/filter to graphic arts students.

## Using a Digital Camera to Explain White Balance

Traditionally, one of the only ways to teach students about the effect of light was to force the issue by showing them the same image illuminated simultaneously by varying light sources using a device such as the GTI CRD-1 Color Rendition Demonstrator (see Figure 3) (Color Rendition Demonstrators, 2004).

Today, teachers can easily use digital cameras to demonstrate the impact of the light source on a captured photograph. Most digital cameras provide several



Figure 3

preset white balance settings. For example, the Olympus E-20 camera provides the following presets: automatic, 3000°K, 3700°K, 4000°K, 4500°K, 5500°K, 6500°K, and 7500°K. To use this feature, the photographer must measure the color temperature of the light and set the camera to the closest preset. Colors are accurate in images captured when the light source and camera setting agree.

In addition to the presets, the Olympus E-20 camera also allows the photographer to set the camera to any other white point by using a white card: simply fill the viewfinder with a white card (or other white item) illuminated by the light source in question and press the white balance button. In effect, this feature allows the camera to act as a color temperature meter and results in photographs that are more accurate than the presets can provide. The use of the Olympus E-20 camera as an example in no way limits the functions described herein to that device. White balance functions are available on most digital cameras.

On the negative side, most digital cameras, by default, set their internal electronics to automatically accommodate for the color of the light source. The camera, in effect, acts like the human brain. In essence, both our brains and digital cameras are designed in such a way as to automatically search out the “whitest” point within the field of vision and consider it “white.” This automatic correction is not a problem if there really is a white spot in the image. However, if the scene does not contain white, then the camera’s auto white balance function artificially creates one; and the captured image is, as a result, incorrectly color balanced. Students should be taught not to use the auto setting for photographs in which the colors are important.

## Using a Color Card During Photo Shoots

Including a color card as part of a photographic image will provide the photographer, graphic designer, and printer with tools to improve color reproduction. For example, the GretagMacbeth Color Checker is “a checkerboard array of 24 scientifically prepared colored squares in a wide range of colors. Many of these squares represent natural objects of special interest, such as human skin, foliage and blue sky” (GretagMacbeth, 2004). In particular, GretagMacbeth Color Checkers provide white, black, and gray patches that can be used to correct or tweak the white balance using image editing software, such as Photoshop®. They also contain representative flesh

tones and other memory colors that can be used to fine-tune color separations to properly render, for example, African-American, Asian, Hispanic, and Caucasian skin tones. Fields, Nichols, and Waite (2003) provide concrete examples of the use of GretagMacbeth Color Checker when rendering flesh tones.

Students should be taught that in practice the Color Checker is included only on the first photograph of a shoot containing multiple images captured with the same light source. Eventually, adjustments can be made to this first image in an image editing program, such as Photoshop®. Depending upon the image editing software, these series of adjustments can be saved in a macro, such as a Photoshop® “action.” This macro can be used to automatically correct the shoot’s remaining images.

Once the students understand color theory, they are ready for the hands-on photo shoot activity.

## Hands-On Photo Shoot Activity

Teachers can set up a simple or elaborate photo shoot and capture multiple images of the same set using varying light sources and/or the white balance capabilities



Figure 4

of a digital camera. Students should be involved in the staging of the set. The student “model” should come to class the day of the shoot dressed in a combination of gray and bright colors. The remaining students in the class should bring some small, very colorful, items on the day of the shoot. See Figure 4 for an example of a set in a light-controlled space including the placement of the GretagMacbeth Color Checker.

The camera’s preset white balance settings, as well as any “white card white balance” feature, should be utilized in the class “shoot.” Several lighting scenarios should be developed based on the light sources available to the instructor (for example, tungsten, fluorescent, flash, and combinations of these). For each lighting condition, the set should be photographed using each white balance setting that the class camera can accommodate. Complete and accurate documentation of each combination of lighting condition and white balance setting should be recorded on a Photograph Record Sheet (see Figure 7 in the Appendix).

Once the images have been captured, they should immediately be downloaded onto the teacher’s hard drive and displayed for the class using a calibrated monitor or projection system. Careful attention should be paid to the effect of each light source and each camera setting on the resultant image. Teachers should explain which images are correct and why the others are wrong. In addition, teachers should explain how the combination of light source and camera setting resulted in each good—and each incorrect—image.

## Importance of Monitor Calibration

Students must be taught to calibrate (and re-calibrate) their monitors to the CIE D50 standard so that the colors they see on the screen can be properly judged. Monitors that are uncalibrated, or set to their native white points, generally skew colors toward blue. This colorcast must be eliminated.

The relative “warmth” of a monitor set to D50 may surprise students. Many will balk at the change. Teachers should stand firm and emphasize that D50 is not only correct but that the calibration should be checked and adjusted frequently (i.e. daily) to make sure the setting remains accurate. Either the operating system’s built-in visually based calibrator or an external third party monitor calibrator, such as X-Rite’s Monaco Optix system or

PANTONE’s Spyder2, may be used.

## Correcting Improperly White-Balanced Photos

The popular image editing software, Photoshop®, has three tools in the Levels and Curves dialog boxes that make it easy to correct improperly white-balanced photos: the “Set White Point,” “Set Gray Point” and “Set Black Point” tools (see Figure 5).

Assuming that the GretagMacbeth Color Checker has been included as part of the image being adjusted, it is a simple matter to click on a gray patch of the Color Checker with the “Set Gray Point” tool. Use of this tool almost always causes an incorrectly white balanced image to become more accurate. If necessary, the “Set White Point” and “Set Black Point” tools can be used to further refine the white balance. Caution is necessary when using the “Set White Point” tool so that the highlights do not become too white.

Using the “Set White Point,” “Set Gray Point,” and “Set Black Point” tools, it is possible to correct most incorrect images captured during the photo shoot so that they closely match those in which the light source and camera settings agree.

When correcting the first image of a shoot captured using a given light source, the process can be recorded



Figure 5

using Photoshop's Actions command so that the process can be replayed on subsequent images.

It is also important for students to learn the importance of flesh tones and other memory colors and how to adjust them using Photoshop's functions. If the photograph in question contains an image of a human, it is important to check the flesh tones. *CMYK Color, Visual & Digital References for Professionals* (Fields, Nichols, and Waite, 2003) includes example photographs of persons from each racial group along with representative color content for their skin tones. In addition, examples of what happens when flesh tones are improperly color balanced are provided.

A complete set of instructions for using image editing software to correct photos for white balance is provided in the Appendix of this paper.

## Conclusion

By presenting the theory and the hands-on demonstration suggested in this paper, students can quickly and effectively grasp the impact of the light source on a captured image. In addition, students will learn to use the somewhat obscure white balance settings available on most digital cameras. They will learn the importance of calibrating their monitors to industry standards and how to correct improperly white balanced photographs using an image editing program, such as Photoshop®.

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## Biographical Information

Dr. Jerry Waite is the coordinator of graphic communications technology in the University of Houston's College of Technology. Dr. Waite has been involved in the printing and publishing business since he was a high school freshman at the Don Bosco Technical Institute in Southern California. Dr. Waite earned his teaching certification and bachelor's and masters degrees in Graphic Arts at California State University, Los Angeles. UCLA was his home during his doctoral studies. He taught graphic arts at the high school and community college levels in Southern California for nineteen years.

In 1993, at the request of the University of Houston, the Printing Industries of the Gulf Coast, and the Texas Printing Education Foundation, Dr. Waite moved to Houston to begin the graphic communications technology curriculum in the UH College of Technology. He currently teaches most of the undergraduate credit courses in graphic communications technology.

Dr. Waite has held several offices in the International Graphic Arts Education Association, including President, First Vice-President, and Regional Vice-President. He is Treasurer of the Accreditation Council for Collegiate Graphic Communications and the editor of the *Visual Communications Journal*.

Cheryl Willis is an Associate Professor of Information Systems Technology at the University of Houston. She received her Ph.D. in Curriculum and Instruction from the University of Florida. Her teaching focus is primarily on applications development and database management. Her research interests include curriculum revision processes for career and technology programs; service learning in information technology undergraduate programs and the use of emerging technologies in undergraduate teaching. She is involved in studying the use of

tablet PCs in a m(obile) Learning Lab. She has developed curriculum for business education and information technology at the secondary, post-secondary, undergraduate, and graduate levels.

Garth Oliver taught Graphic Communications at the high school level in Hawaii and South Carolina for five years, he taught in the Graphic Communications department for four years at Clemson University, and is currently a Visual Communications Lecturer at the University of Houston. He teaches Visual Communications (GRTC 3353), Press I (GRTC 3352), and Materials and Processes (GRTC 3350) at the University of Houston's Central Campus. He completed his Bachelor's in Secondary Education, majoring in Technology Education, at Southeast Missouri State University in Cape Girardeau, Missouri in 1994. He received his Master's in Administration and Curriculum from Gonzaga University in 1997. He is expecting his Ed.D. in Vocational Technical Education from Clemson University in the summer of 2005. The working title of his dissertation is "Apparent Quality of Sublima® halftone screening as compared to CristalRaster® and conventional screening in commercial offset lithography."

## Appendix

### *Step-by-Step Instructions for a Classroom Demonstration*

#### **Equipment, Materials, and Facilities List**

1. Room in which lighting can be controlled (a photographic darkroom is appropriate).
2. Multiple light sources (for example, D50 fluorescent lighting, D50 plus red safelights, incandescent studio lights, or camera flash). These light sources can be as simple or elaborate as necessary.
3. Digital still camera that allows the White Balance to be adjusted. Check your batteries.
4. Tripod
5. Memory card that will hold sufficient photos (40–50 photos is an appropriate number) at the camera's highest resolution. You may want to erase the memory card.
6. A "set" of some sort, such as a table, chair, and potted plant.
7. GretagMacbeth Color Checker or equivalent (large gray-scale, neutral gray card)
8. Photograph Record Sheet (attached)
9. Computer(s) equipped with Adobe Photoshop 4® or above and iPhoto® or Adobe Photoshop Album® or equivalent.
10. A teacher's computer workstation with LCD projector is very useful.

#### **Prior to the Lesson**

1. Enlist the assistance of a student to be the "model" for the upcoming photo shoot. The student should come to class dressed in a combination of neutral (gray) and bright colors.
2. Ask all remaining students to bring some small very colorful item to class on the day of the photo shoot.
3. Prepare the "set" in your light-controlled space (see Figure 4).
4. Mount the digital camera and flash on the tripod.

#### **The Photoshoot**

1. Pose the model in the set previously prepared above (see Figure 4).
2. Position the students' colorful items.
3. Position the Gretag-Macbeth Color Checker or other gray card as shown in the example.
4. Identify a photographer and a recorder. The instructor may act in either capacity or may have two students assume these roles.
5. Illuminate the set using a given set of lights (this will be known as lighting scenario #1) and record that scenario on the Photograph Record Sheet.
6. Photograph the set using each white balance setting your camera can accommodate. Be sure to keep accurate and complete records of each shot including frame number, lighting condition, and white balance setting.
7. Illuminate the set with a different kind of lighting (lighting scenario #2) and record that scenario on the Photograph Record Sheet.
8. Photograph the set using each white balance setting your camera can accommodate. Be sure to keep accurate and complete records of each shot including frame number, lighting condition, and white balance setting.
9. Repeat steps 7–8 until all lighting conditions have been exhausted.

## Downloading and Sharing

1. Connect the digital camera to the instructor's computer and download the photos into iPhoto® or Adobe Photoshop Album® or equivalent.
2. If possible, project the photo album so that all students can see.
3. Have your "model" close at hand so you can compare that individual's flesh tones and clothing colors to those displayed on the computer or LCD screen.
4. Describe each of the several photos captured with lighting scenario #1. (Use the Photograph Record Sheet to determine which image was photographed with each lighting scenario and camera setting.) Explain why each photograph appears so different from the others shot in the same lighting.
5. Explain the differences between the photos shot using lighting scenario #2 and those shot with lighting scenario #1 using the same camera setting. Explain that both the camera's white balance setting and the light source must agree to get good photos the first time.
6. Share all or some of the photos with your students using the network, server, memory cards, disks, or whatever media you have at your disposal.



Figure 6

## Quick and Easy White Balance Correction in Photoshop®

1. Use iPhoto® or Adobe Photoshop Album® to open an incorrectly color-balanced photograph in Photoshop®. (You may want to set the preferences in iPhoto® or Album so that the program opens a selected photograph in Photoshop®.)
2. Open the Curves Dialog Box.
3. Select the Gray Balance Tool.
4. Move the cursor over any one of the gray-scale swatches along the bottom of the GretagMacbeth Color Checker (or other gray scale or card) (see Figure 5).
5. Click on the gray swatches—one at a time—and observe the instant improvement of the color balance.
6. You may also wish to experiment with the Black Tool. Select it, then move the cursor over the blackest swatch on the GretagMacbeth Color Checker and click (see Figure 6).
7. When you are finished, click "OK" to return to the photograph.
8. Save the file if desired. It is most appropriate to save it with a different name: for example, append the phrase "white\_balanced" to the end of the name.
9. Open several different incorrectly photographed images and use the Gray Balance Tool and Black Tool to correct them.
10. Explain to students that they can save the changes they apply to the white balance of the image by clicking the "Save" button in the Curves dialog box.
  - a. This saved curve can then be applied to every other image shot with the same lighting and white balance setting by selecting Load in the Curves dialog box.
  - b. The saved curve means that only one photograph—the initial one—of a photo shoot needs to have the GretagMacbeth Color Checker, other gray scale, or card included. All other images can be instantly corrected—even in a batch process—by applying the saved curve.

## Photograph Record Sheet

Image Number	Lighting Scenario	Camera Light Balance Setting
1		
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Figure 7