Using ColorThink and Online Teaching

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Introduction
The author taught many years of color reproduction-related courses to college students in print media and graphic communication programs. He used to think that hands-on lab assignment was only possible in-person in laboratory settings. His recent online teaching experiences proved him wrong. This document describes a lab assignment, Using ColorThink, in an online course, administered by Wuhan University, in the summer of 2020. Due to the coronavirus pandemic, no one was on campus. All eleven students were spread out across many provinces in China. As an adjunct instructor, located in North America, the author was able to connect with his students via Zoom for synchronous communication and relied on WeChat and email for asynchronous communication.

Background
Printing-Process Control and Standardization was offered as a 4-week, 2-credit undergraduate professional elective course in the Wuhan University Summer School International Program. The lab assignment took place in the 4th week. Students learned colorimetry and ICC color management via video-taped lectures and chapter readings (Chung, 2020) in previous weeks. They understood that International Color Consortium (ICC) addresses color management at operating system’s (OS) level. They recognize that characterized reference printing conditions (CRPC), the same as look-up-tables of ICC profiles, define the relationship between CMYK (input data) and printed color.

The ICC web site contains a wealth of up-to-date information, including ICC specifications, ISO-sanctioned and registered ICC profiles, including CRPC1–CRPC7. Students were directed to the ICC web site, www.color.org > ICC Profile Registry, to download two of the seven (CRPC1–CRPC7) ICC profiles. To introduce different hands-on experiences, CRPC1 and CRPC4 were assigned to a fraction of the class, CRPC2 and CRPC5 were assigned to the
other fraction of the class, CRPC3 and CRPC6 were assigned to another fraction of the class, etc.

They were asked to study an instructional video, using Camtasia 3 screen-and-voice capturing software, introducing major features of the ColorThink Pro 3. In a nutshell, ColorThink Pro 3 can open ICC profiles, color images, and color lists, perform color conversions, display color-managed images and their differences, compute color differences, and many other color analysis functions.

Lab Procedure
Students attended Zoom meetings three times a week. During the sessions the instructor went over examples and answered questions before students began working on the lab assignment. Although students had good command of the English language, both English and Chinese were used in the classroom. The lab report, using the English only, was due two days later.

There were three lab objectives that covered basic and advanced concepts. The first lab objective was to analyze two of the seven CRPC profiles using ColorThink Pro 3 software. In other words, students were asked to compare two CMYK device gamut’s in 3-D, 2-D, spider plot, and set up a data table to compare CIELAB values of CMYK solids, paper, and ΔE00 between them. Students were asked to discuss pros and cons of each graph. The second lab objective was to apply the assigned ICC profiles to students’ own RGB images in RGB-to-CMYK color image reproduction workflows. In addition to simulating the visual difference of two sRGB-to-CMYK workflows, students were asked to show vector plots of custom sampled image pixels. The third lab objective was to assess the round-trip error of two CMYK ICC profiles. The legacy CMYK file, IT874_CMYK_1617.txt, were was provided as the start of a color worksheet. Students were asked to discuss the round-trip error, in terms of the 95th percentile ΔE00, as a baseline for determining color matching of Pantone colors using ICC-based color management workflows.

The author contacted CHROMiX, stated his intention, and asked for a one-month gratis license of the ColorThink Pro 3.0.5 (WIN) so that students could gain some hands-on experience. The process from obtaining the license to installing the software to students’ PCs went smoothly. The author also found Idealliance’s Guide to Print Production, Version 20.1 (2020) a valuable reference at www.idealliance.org.

Results and Discussions
Figure 1 illustrates the comparison of two printers’ color gamuts in 3-D (left), 2-D (center), and spider (right) plots. In this case, a student compared CRPC4 (the smaller gamut) and CRPC7 (the larger gamut). Other students compared CRPC1 and CRPC4, CRPC2 and CRPC5, and CRPC3 and CRPC6, respectively.

Figure 1
Gamut comparison between CRPC4 and CRPC7.

Everyone observed that the 3-D gamut plot is visual, comprehensive, but difficult to document in the report; the 2-D plot is brief, cursory, and can be deceiving because the third (L*) dimension is missing. However, the 3-D plot with an L* slicer, as shown in Figure 2, proves to be a useful feature to compare the gamut size at a constant (in this case, 50) L* plane.

Figure 2
3-D gamut with a L* slicer between CRPC4 and CRPC7.

While 2-D and 3-D plots emphasize gamut boundaries, the spider plot offers process control (solid coloration) insight. It compliments with the data table (Table 1) that provides CIELAB values of the white point and solid coloration. Color differences of the white point and solid coloration between CRPC4 and CRPC7 printing conditions are also shown.
Table 1
Solid coloration between CRPC4 and CRPC7.

<table>
<thead>
<tr>
<th></th>
<th>CRPC4</th>
<th>CRPC7</th>
</tr>
</thead>
<tbody>
<tr>
<td>L*</td>
<td>55</td>
<td>54</td>
</tr>
<tr>
<td>a*</td>
<td>-36</td>
<td>-42</td>
</tr>
<tr>
<td>b*</td>
<td>-58</td>
<td>-42</td>
</tr>
<tr>
<td>ΔE00</td>
<td>5.0</td>
<td>3.8</td>
</tr>
</tbody>
</table>

The second lab objective, building two RGB-to-CMYK workflows using one’s own pictorial color image, was more interesting than the first lab objective. Figure 3 is a visualization of the sRGB-to-CMYK3 (left) and the sRGB-to-CMYK6 (right) color image reproduction workflows under relative colorimetric rendering intent. This multi-hue, colorful image, from the author, worked well to illustrate the visual difference, i.e., CRPC3 (uncoated paper) shows limited colorfulness than CRPC6 (coated paper).

**Figure 3**
Visualization of sRGB-to-CMYK3 (left) and sRGB-to-CMYK6 (right) workflows.

Figure 3 shows that when gamut compression is inevitable, a “dimmed” color results due to the loss in L* range (including the white point) and chroma. In this case, the CRPC3 reproduction (left) is dimmed more than the CRPC6 reproduction (right).

**Figure 4**
Vector plots of image pixels between sRGB and CRPC3 (left) and CRPC6 (right).

Figure 4 illustrates the vector plot of sampled image pixels between sRGB space to CRPC3 (left) as well as between sRGB space to CRPC6.
Both the 3-D view and the 2-D view indicate that the amount of visual loss in tonality and chroma is proportional to the magnitude of the vectors pointing inward with hue of the image pixels preserved. Thus, a dimmed reproduction (CRPC3) corresponds to the vector plot with larger vectors pointing inward (left). Particularly, there are noticeable chroma loss in the red (tomato) region of the color image.

“Round trip” is a technique of estimating the color conversion error (B-to-A-to-B) of an ICC profile. The round-trip begins from the legacy CMYK file, IT874_CMYK_1617.txt, which is the A or the device space. As shown in Figure 5, reported by Xinwei Wu who is a student in the class, the A-to-B conversion transforms CMYK values into reproducible CIELAB colors. This is followed by the B-to-A conversion (from a specified ICC profile) and, then, the A-to-B conversion of the same ICC profile using the relative colorimetric rendering intent.

Figure 5
Using a worksheet for the round-trip analysis.

The B-to-A-to-B conversion of the color list produces 1,617 ΔE00 values. In a previous lab assignment, students learned how to use Excel to sort the ΔE00 list to generate a cumulative relative frequency (CRF) plot. As shown in Figure 6, also reported by Xinwei Wu in his lab report, the 95th percentile ΔE00 of the CRPC6 is around 1 ΔE00 and the 95th percentile ΔE00 of the CRPC3 is close to 2 ΔE00. This means that when assessing the reproducibility of Pantone colors by a CMYK output device, we should consider “no less than 2 ΔE00” as a color matching tolerance.
Figure 6
Round-trip errors of two ICC profiles, CRPC3 and CRPC6.

Conclusions
ColorThink Pro 3 is an ICC profile inspection utility. It can display the color gamut of a CMYK device in 3-D, 2-D, and spider plots. It can visually simulate color image reproduction workflows and quantitatively show how color reproduction quality is affected by the printing conditions. It can also be used to estimate the inherent color matching error of an ICC profile.

ColorThink Pro 3 was a new software to these students. If color management is the engine of an automobile, this lab assignment gave them a close look at what's underneath the “color management” hood. Many students found the lab assignment interesting, impressive, and important in their education and learning. By having hands-on ColorThink Pro 3, they gained insights into how device gamut influences sampled image pixels, and visual quality of the color image reproduction.

The author has used Microsoft Excel and Adobe Photoshop successfully in many lab assignments. Excel is good for number-crunching and graphing. Photoshop is good for visualization of color image reproduction and brand color reproduction. ColorThink is good for both number-crunching of digital data between device and PCS (Profile Connection Space), and visualizing color images in various color reproduction workflows. He recommends this lab assignment to interested faculty members in their academic endeavors highly.

Acknowledgments
The author wishes to thank Professor Xiaoxia Wan for inviting him to teach the online course in Wuhan University. He also wishes to thank Mr. Rick Hatmaker and CHROMiX for making ColorThink Pro 3.0.5 available during his teaching. Without the software support, the lab assignment would not have been realized. Last, but not the least, he wants to acknowledge the interactions he received from his students, particularly, Xinwei Wu, during his teaching.

References


About the Author
Robert Chung is Professor Emeritus of RIT School of Media Sciences. He is the author of the book, Printing-Process Control and Standardization, published by RIT Press, in 2020. He has published over 100 technical papers in printing process control and color management. He was the convener of ISO/TC130/WG13, the working group responsible for developing printing conformity assessment standards from 2010 until his retirement in 2016. Bob was active in the development of CGATS standards concerning printing tolerance and the dataset conformity assessment for printing from digital data across multiple technologies. Bob was the recipient of the 2006 Michael H. Bruno TAGA Award for Outstanding Contribution to the Graphic Arts Industry, and the recipient of the 2007 GCEA (Graphic Communication Education Association) Kagy/Prust Life Achievement Award. He can be reached at rycppr@rit.edu.