



# Visual Communications JOURNAL

## FALL 2006

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### About the Journal

The *Visual Communications Journal* serves as the official journal of the International Graphic Arts Education Association, Inc., and provides a professional communicative link for educators and industry personnel associated with design, presentation, management, and reproduction of graphic forms of communication. Manuscripts submitted for publication are subject to peer review by the Association and the views and opinions expressed herein are those of authors and do not necessarily reflect the policy or the views of the IGAEA

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\* David Dailey was President of the IGAEA when the *Journal* was published. His article was subjected to double-blind review.

\*\* Jerry Waite served as the editor of this *Journal*. However, his article was subjected to double-blind review.

# Editor's Note

By Jerry J. Waite, Ed.d, University Of Houston College of Technology

The Graphic Arts teaching profession seems to be getting more and more productive in terms of research and publication. In the Spring of 2006, the IGAEA Board of Directors approved a motion to double the number of issues of the *Visual Communications Journal* from one-per-year to two. The first bi-annual edition, published in Spring 2006 and available for download at [www.igaea.org](http://www.igaea.org), contained four peer-reviewed articles. This issue, published in Fall 2006, contains eight more articles! Congratulations to the IGAEA members who conducted and disseminated so much first-class research!

This issue of the *Visual Communications Journal* has something for everyone involved in graphic arts and graphic arts education. Printing industry executives and faculty who specialize in printing management will enjoy an article by Ken Macro from California Polytechnic State University. Ken explores the possibilities of using blogs, Podcasting, and e-learning to improve the print sales experience, disseminate knowledge, and facilitate training. Managers and print management instructors will also enjoy Greg D'Amico's study related to overcoming pitfalls when implementing Print Management Information Systems in commercial printing firms.

Middle- and high-school graphic arts teachers will certainly enjoy reading Carl Blue's article in which he demonstrates how graphic communication units of instruction developed by a multi-state consortium have a significant impact on students' learning of technology, mathematics, and science.

Faculty who teach screen-printing will appreciate David Dailey's easy-to-use test to determine the best screen mesh count and angle to avoid moiré. Instructors at all levels who are interested in color management will enjoy Yung-Cheng Hsieh's description of a process to calibrate and characterize Epson and HP ink-jet printers for printing on specially prepared cloth substrates. And, I hope all print teachers will find my paper on teaching printing industry guidelines to be useful.

College and university-level graphics instructors will see immediate uses for the type of interdisciplinary learning center that La Verne Abe Harris describes in her paper about the Arizona State University IDEaLaboratory. This unique organization has research, development, entrepreneurial, and curriculum-development agendas that relate to, web-sites, video, print, and graphic design.

Finally, teachers of graphic design, in particular, will find that Kelly Glentz Brush's article on PDF portfolio creation contains an easy-to-use process that students can follow when converting their hard-copy portfolios to the ubiquitous portable document format. PDF portfolios can be published to the web or included with resumes and cover letters when graduates search for jobs. In this way, prospective employers can peruse an applicant's work before a formal job interview.

As is often the case in our small-but-productive profession, articles that appear in this edition of the *Visual Communications Journal* were written by members of the IGAEA's Board of Directors (President David Dailey) or by the *Journal's* editor (me). These two articles were submitted to the same peer-review scrutiny as the other papers and were accepted using a double-blind review process. Documentation regarding the voting on these two articles is available by contacting me at [jwaite@uh.edu](mailto:jwaite@uh.edu).

Finally, thanks to the *Journal's* editorial review board. I truly appreciate the time and effort invested by Cynthia Gillispie-Johnson, James Tenorio, Zeke Prust, Bob Chung, Lenore Collins, and Mark Snyder. However, *super* thanks goes to Malcolm Keif who not only reviewed his share of submissions but also hosted the 2006 IGAEA Conference... *at the same time.*





# Moblogging, Podcasting, and e-Learning: The Evolution of a Mobile Work Force

by Ken Macro, California Polytechnic State University

As global consolidations and competition continue to occur, workforces are becoming larger and more difficult to maintain. Therefore, disseminating information and knowledge presents many challenges to knowledge and learning management initiatives within progressive corporations. Fortunately, with the evolution of cellular and wireless technology, organizations are tapping into this vast market to keep their workforce up to date with real-time applicable business data and knowledge that gives them the advantage when working with current and prospective customers. Providing concentrated, real-time, applicable, and customized knowledge to the workforce when it is requested and needed is the key to any knowledge-related management initiative. This study provides a brief analysis of this technology as a means for disseminating knowledge and facilitating training.

## It's a Very Graphic Problem

A sales representative for Verizon Yellow Pages arrives for a pre-scheduled appointment with a client. The sales representative carries boxes in the trunk of her car containing ad specification sheets from the clients in her territory from the past two years. She takes ten minutes prior to the call to find the client's individual specification sheets and then takes a moment to review the layout, the financial information, the logistics associated with ad placement, and applicable headings. When greeting the client, the client responds that they were not happy with the ad placed in the phone directory the previous year because artwork was inadvertently left out of the advertisement. The sales representative riffles through the client's folder to locate the artwork and is unsuccessful. The client—obviously disturbed—walks over to a cabinet, pulls out a hand-drawn board containing the artwork, makes a photocopy, and hands it to the sales representative. During the sales call, prior to signing the contract, the client asks to see what other class headings his competitor has selected to place their advertisements. The sales representative, who is unfamiliar with the competitor, graciously smiles and tells the client that she will get back to him after she returns to the office and talks to her colleague who handles that account. The customer, again disturbed, signs the contract with unspoken remorse.

This scenario exhibits a normal sales call in the life of a yellow pages ad representative performing a sales campaign in a specific two-week geographical canvas. Having important and pertinent information that is easily accessible and obtainable is paramount to the success of a sales campaign, and—as their competitors (independent yellow page directory publishers) canvas the areas before them—customers become concerned with turn-around, costs, and accuracy of their ads placed in a the myriad of telephone directories now barraging the very communities where they do business. This is precisely why integrating mobile technology with sales solutions, training, and linking it all with corporate financial databases and content archives can make a sales call more efficient, informative, direct, and most importantly, empower the sales representative to handle questions, concerns, and problems immediately with amicable results.

Gayle Barnhart, President of Adsource, Inc., a marketing consultant in the area of yellow page planning headquartered in Peninsula, Ohio (2005) says,

*Integrated wireless technology is the future of yellow page sales programs. Having the ability to punch up a client on my PDA, view a PDF of the ad that was placed in last year's directory, review the headings, and the applicable contract fees, and, at the same time pull up important marketing statistics associated with header placement, and competitor profiles, allows me to be in control of the call appeasing the customer on any problems that he or she may have during the process. (G. Barnhart, Personal Communication, June 22, 2005).*

From a graphical perspective, Barnhart also envisions that the technology will be able to scan artwork, automatically paginate the ad in the appropriate location, and produce a printed proof (known in the industry as a showproof) immediately from a local printer for final review and approval (Barnhart, 2005). Additionally, Barnhart (2005) adds, "Having the ability to pull up sales training video and materials would be a major benefit for newer sales representatives who are inexperienced in the industry." Such immediate access would provide applicable information to the sales representative prior to the call making for a fresh, controlled, and amiable selling transaction.

## Technology Without the Strings Attached

New technology—most specifically, integrated wireless and cellular technology—will become a primary venue for delivering information and training to a globally expanding workforce. The traditional models of classroom-based learning and collaborative learning will be supplemented with mobile training models that will provide highly individualized and pertinent information to the employee at the precise time of need in order to assist in successfully transacting a task and/or duty associated with that employee's job requirements. As Chris von Koschembahr posits,

*Just as PDAs and laptops have allowed professionals to communicate while they are working "mobile" or on the road, these tools also enhance the benefits of e-learning by making vital learning material, once available only from the desktop, accessible while learners are in a cab on the way to an important sales meeting or waiting to board an airplane, for example. Just a few minutes of "dead time," which are often wasted, can be transformed into incremental ongoing learning opportunities. (von Koschembahr, 2005, p.1).*

When assessing the vastness of efficiencies associated with mobile technology and knowledge acquisition and dissemination, Jonathan Levy (2005) writes, "The power of the new technologies lies in their ability to leverage the knowledge of knowledge workers both individually and collectively. Powerful solutions are driven from the bottom up, not from the top down. Top-down classes don't leverage the knowledge value of a knowledge workforce; just-in-time, personalized solutions, aggregated in real time around the learner, by the learner, do" (p. 2). Providing instantaneous knowledge that is specific in nature to the employee and solicited by the employee (or learner) is the unconditional benefit to mobile technology and a coveted successful knowledge-related management initiative.

United States Gypsum Corporation (USG) manufacturers and distributes building materials worldwide. Because USG's workforce, comprised of over 13,500 employees placed all over the world, is so vast and decentralized, it is imperative that the Web be used as a venue in which to disseminate knowledge and facilitate training (Summerfield, 2005). In addition to the execution of an expansive knowledge portal, which consists of customizable fields that

exhibit real-time information pertaining to sales, production, and distribution, there also exist venues for accessing training materials that are applicable to personnel in many different departments.

Web conferencing has also become a core venue for disseminating USG information. Summerfield (2005) writes, quoting Mike Garber, USG's director of training and development, "We are increasingly using Web conferencing to develop an understanding of new processes and procedures within the organization, as opposed to having everyone come together for a meeting involving training around a new process" (p. 50). According to Garber, they use webcasting to roll out changes that affect everyone throughout the corporation. This type of venue for disseminating knowledge is quick, efficient, thorough, and provides additional links for employees to peruse when in need of additional information or knowledge pertaining to the matter.

Webcasting can be facilitated on hand-held cellular devices such as PDAs, pocket PCs, and cell phones. Such technology provides instantaneous synchronous participation of the entire workforce when the webcasting takes place. Summerfield (2005) quotes Mike Garber, "The way we see it, the organization that has the ability to learn and to apply this learning faster is going to be the winner in the marketplace" (p. 50).

According to On-Stat/MDR, a marketing research corporation specializing in communications industry, there will be over 94 million mobile workers using mobile technology in 2005, which is 40% of all U.S. employment (Edwards, 2005). With the evolution of the cell phone, PDAs, Pocket PCs, iPods, Blackberries, Mp3s, tablet PCs, Wi-Fi-enabled laptops, and the expansion of affordable wireless broadband service, mobile communication has exploded providing learning organizations with an opportunity to disseminate real-time information, knowledge, and training. Ron Edwards (2005) writes, "A workforce that is on the move and working in different locations poses a challenge, but keeping these employees informed and engaged enables faster detection of opportunities and problems, and working together can help to further develop collaborative solutions" (p. 51). Collaboration assures that the information is received, decoded, and engaged, thus engaging the employee in the content and affirming—transparently—that some form of learning has taken place.

## The iPodification of e-Learning

Instant messaging, discussion boards, and document sharing venues currently provide for an open means to post knowledge and information at any time or anywhere. Thus, on-line communities have formed. These communities engage and empower customers and supply-chain vendors to contribute to applicable dialog and to access the vast pool of knowledge that grows from each transaction. As a result, customer retention is increased, consumer awareness is incited, and better business analysis leads to a more informed group. Aside from instant messaging—which is synchronous in nature—posting to discussion boards, drop boxes, and e-mails can be made at the convenience of the participants. This asynchronous model is referred to as “blogging,” short for web-logging (Edwards, 2005). This form of knowledge dissemination allows employees the opportunity to publish information to a Web site using a cell phone, PDA, or laptop at a time that is convenient to them. Using mobile technology has generated the new term, “moblogging” short for mobile “blogging” (Edwards, 2005, p. 52).

Another related approach to mobile knowledge dissemination is that known as “podcasting.” According to Edwards (2005), podcasting (a combination of the words “iPod and broadcasting”) assists in the creation of content that is pertinent to corporate communication or learning teams (p. 52). Edwards (2005) writes, “Content could include audio from business leaders, leadership programs, cultural change content and so on, and it would be available whether the employee is at home, in the car listening to a CD, on the move with an mp3 player, or using a cell phone that is a mp3-enabled” (p. 52). iPods have gained significant market share and have increased in popularity. Because they are affordable and, undoubtedly, powerful, there are organizations in the UK that are considering distributing iPods to workshop participants that contain pre-loaded audio-based lectures and discussions (Edwards, 2005).

Mobile technology has sparked a new learning movement referred to as location-based learning. This model relies on mobile technology to both transmit and receive applicable knowledge and information. Edwards (2005) posits, “The system automatically delivers just-in-time content to a handset based on the worker’s location in the manufacturing facility and checks so see if they have the right equipment and qualification” (p. 53). Currently being beta-


tested through Symbol, MIT, and a top learning and technology firm, this form of learning milieu is anticipated to grow as location-based detection-enabled cell phone technology (for the 911 initiative) develops.

How an organization delivers knowledge, disseminates information, or facilitates learning is the impending dilemma facing growing organizations across the globe today. Without a doubt, however, technology will play a major role in organizational sustainability. Regardless, all learning strategies will have to be identified, analyzed, and re-invented in order to codify, organize, archive, and distribute knowledge to a fast-paced, globally-competitive, highly-mobile workforce of the future. “Whether the subject matter is a new body of regulations, an evolving product line or emerging strategic priorities,” writes Hemant Minocha (2005), “organizations must find ways to efficiently and effectively keep their workforce educated to keep pace in a corporate environment with greater time and constraints than ever before” (p. 20). Perhaps integrating mobile technology is the key.

Peter Drucker (2001) wrote, “Technology is not nature, but humanity. It is not about tools; it is about how people work. It is equally about how they live and how they think” (p. 343). As cellular telephones continue to gain placement in markets across the world and are placed in the majority of pockets of the citizens who inhabit these markets, the terms such as podcasting and moblogging will morph into the linguistic patterns of a culture essentially weaned on this wireless instantaneous technology. Learning and knowledge managers alike will also be forced to understand and integrate this technology into their schemes of facilitation and distribution. For this technology—embedded in the culture—will appropriately supplement the core competencies of how people work, how they think, and how they live.

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***This is a juried article***



# Printing Industry Guidelines for Print Students Part One: Guideline Overview and File Format Considerations

by Jerry Waite, Ed.D., University of Houston College of Technology

## Abstract

Printing industry associations provide guidebooks, such as SNAP, GRACoL, SWOP, and FIRST, to help graphic designers prepare files that pass intact through digital print workflows. As these guidelines gain greater acceptance by printers, customer service professionals, technical sales representatives, and technicians will be increasingly called upon to effectively explain the guidelines to graphic designers. In addition, print technicians must be able to shepherd guideline-compliant documents through the print workflow. This literature review introduces SNAP, GRACoL, SWOP, and FIRST and focuses on file format considerations that print students must know to be effective practitioners in the twenty-first century printing industry.

## Introduction

Over the past decade, there has been an unmistakable trend in printing companies to downsize prepress departments. A firm may have once employed dozens of people who operated cameras, retouched film, duplicated films, operated scanners, assembled film onto flats, and made proofs and plates. Today, that same firm may function with five or six prepress personnel who do little to create the components of a job. Prepress employees seldom create page layouts, do scanning, perform color separations, or implement color corrections. Instead, prepress personnel preflight, impose, trap, proof, raster-image-process (RIP), and output plates.

Teachers and professors of graphic communications technology must make constant adaptations to their curricula in order to keep up with the printing and publishing industry. Process camera work, film retouching, and stripping were fundamentals of graphic communications courses less than 20 years ago. Ten years ago, page layout, scanning, image editing, color separation, imagesetting, imposition, and analog platemaking were curricular musts for graphic arts classes. Today, due to fundamental shifts in print workflow and industry-approved guidelines, students of print must learn fundamentally different technologies than in the late twentieth century.

In the past, graphic designers had to rely on printers and/or prepress service providers to purchase prohibitively expen-

sive equipment and hire specialized, highly trained, and well paid employees to run them. A graphic designer or ad agency can now purchase a powerful computer workstation, high-resolution scanner, and a suite of image creation, editing, and layout software for less than \$10,000. Creatives have taken advantage of these low prices to outfit themselves with everything they need to do the work that was once accomplished by numerous prepress employees. However, a graphic designer, working in isolation from those who will ultimately put ink on paper, cannot possibly know all the interactions and permutations between ink, paper, process, and press. In fact, the designer may not even know which company is going to produce the end product. Thus, work skillfully and effectively designed using all the right software may not result in a printed job that meets customer needs.

Printers do not assume that files submitted by designers are accurate, so they preflight (check) files before putting them into production. However, the burden of preparing accurate files has been essentially pushed out of the prepress department to the graphic designer. As a result, the prepress departments of many printing companies now specialize in just a few activities: preflighting, imposition, trapping, RIPping, proofing, and platesetting. Most importantly, price quotations often include only these prepress functions. File intervention activities are often treated as customer alterations and billed separately.

## Purpose

The purpose of this paper is to introduce the printing industry guidelines, extract from those guidelines essential file format considerations that students of print production and management must learn, provide an overview of hardware/software solutions that can be used by graphic arts teachers to prepare their students for roles in the contemporary printing and publishing industry, and recommend further study. This paper is one of three related papers: *What to Teach Graphic Design Students About Printing Industry Guidelines* (Waite, 2006) focuses on preparing graphic design students for guideline-centric print workflows. This paper focuses on identifying the guidelines published by the printing industry's niches: web offset publication, newspapers, commercial offset printing, and flexography. In addition, it details file format considerations recommended by each of

these four groups. The third paper, *Printing Industry Guidelines for Print Students Part Two: Printing Process Control and Color Separation* (Waite, submitted) highlights process control methods recommended by the guidelines and how process control impacts color separation techniques.

Members of the committees promulgating the guidelines provided extensive input to this paper. Special thanks are due to GRACoL Committee Chair, Don Hutcheson, and Joseph Marin, senior prepress technologist for Printing Industries of America/Graphic Arts Technical Foundation for the inordinate amount of time they spent insuring that the content of this paper is both accurate and timely.

## Guidelines Aim to Minimize Faulty Files

To minimize faulty files, high-volume printers—those who print large quantities of products by gravure, flexography, and web offset (particularly publications printers)—banded together and formulated documents that provided guidelines for both designer and printer. In theory, if the designer and printer follow the guidelines, the final product will appear as desired by the customer. These guidelines were gradually introduced and, in many cases, are now demanded by printers. Incoming files that do not meet the guidelines may be rejected.

Encouraged by the apparent success of high-volume printing process specifications, commercial printers are in the process of formulating their own guidelines. Once these guidelines are validated, files for short-to-medium run printing jobs may have to comply with them.

## What Students of Print Need to Know

Because of the increasing emphasis on industry-sponsored guidelines, it is vital for students of print to know, understand, and be able to explain those guidelines to a wide variety of people. Printing company sales support individuals, such as customer service and technical sales representatives, will be increasingly called upon to explain industry guidelines to graphic designers so that files can be prepared correctly from the outset. On the other hand, printing company technicians' roles will change so that they will primarily be responsible for: 1) informing customers which industry-standard International Color Consortium (ICC) color profile (such as U.S. Web Coated SWOP-v2) to use when separating colors or creating and

disseminating company-specific color specifications so that color separation software can be properly set by graphic designers; 2) preflighting incoming documents to make sure they meet the proper guidelines; and 3) imposing, trapping, RIPping, proofing, and outputting the job to plate or digital press.

To be the most effective, students being prepared to work in the printing industry as technicians, sales support staff, supervisors, and managers must be taught not only the specific functions of contemporary prepress (preflighting, imposition, trapping, RIPping, proofing, and outputting) but also how to implement industry guidelines during file preparation. Because document creation is seldom accomplished within contemporary printing companies, it is no longer sufficient for print students to learn only how to create page layout files, pixel-based images, and vector graphics based on industry standards. Yes, print students must know these operations well enough to be able to explain them to graphic designers (see the first of this series of papers, *What to Teach Graphic Design Students About Printing Industry Guidelines* by Waite, 2006). However, their knowledge must also encompass the process of shepherding documents created by others through the printing workflow.

## Printing Industry Guidelines

The dissemination of the *Specifications for Web Offset Publications* (SWOP) was the first attempt by the printing industry to promulgate specifications. After beginning discussions in 1974, a group of graphic arts industry representatives wrote and published the first SWOP booklet in 1976. SWOP, updated nine times since first disseminated, provides “specifications for everyone involved in graphic arts workflow, which includes all forms of magazine advertising and editorial input, whether analog or digital” (SWOP, 2005). For the most part, printers using the gravure printing process also abide by—and expect compliance to—SWOP. SWOP can be obtained at <http://www.swop.org/>

The *Specifications for Newsprint Advertising Production* (SNAP) were originally published in 1984 and are intended for “advertisers, advertising agencies, publishers, pre-press managers, material suppliers, and commercial and newspaper printers” (Newspaper Association of America, 2000). These guidelines are applicable to newspapers and advertising inserts printed by offset lithography, direct lithography, letterpress, and flexography. SNAP can be obtained at <http://www.naa.org/artpage.cfm?AID=1451&SID=214>

The Flexographic Technical Association first published the *Flexographic Image Reproduction Specifications and Tolerances* (FIRST) in 1997. FIRST, which was subsequently revised in 1999 and 2003, provides “all participants in the flexographic reproduction process with a common set of guidelines, tutorials, and data that can be used as communication and production tools” (Flexographic Technical Association, 1999). FIRST focuses primarily on the production of packaging using the flexographic process on film, corrugated board, paper, and paperboard. FIRST may be obtained at <http://www.ftastore.com/store/>.

In 1996, the Graphic Communications Association, now IDEAlliance, formed a task force to “develop a document containing general guidelines and recommendations that could be used as a reference source across the industry for quality color printing” (IDEAlliance, (2001). The resulting guidelines, known as the *General Requirements for Applications in Commercial Offset Lithography* (GRACoL), help print buyers, designers, and specifiers work more effectively with print suppliers. At the time of this writing, GRACoL specifications were still being perfected based on measurements from a series of press trials conducted in 2004–2005. New GRACoL specifications for commercial printing on Grade 1 paper were scheduled to be published in the seventh edition of GRACoL in early 2006. Up-to-date GRACoL information can be obtained at <http://www.gracol.org/>.

## Why Teach Industry Guidelines?

Members of the GRACoL Committee were asked, through an e-mail-based survey, to identify the most important thing about GRACoL that they think college students preparing for careers in graphic communications should know about. The full text of their comments is provided in the a companion paper, *What to Teach Graphic Design Students About Printing Industry Guidelines* (Waite, 2006).

Several themes permeate their comments, themes that instructors and students of print ought not ignore. First is the issue of communication. Guidelines, such as SWOP, SNAP, FIRST, and GRACoL, all facilitate communication and understanding between client and printer. Since designers are now doing much of the work formerly accomplished in printing companies, this communication is essential if a project is to be effectively produced.

A second theme is consistency and stability. Guidelines enable designers to create projects with a particular goal in

mind. Without guidelines, a job would have to be designed for a particular press in a particular plant using a particular paper and particular ink. Using guidelines, a designer could create one set of files for an ad to be produced in numerous magazines that adhere to SWOP. Of course, another set of files would be required for a newsprint reproduction of the ad. However, a different file would not be necessary for Magazine A, Magazine B, and so forth. Consistency is also valuable for the printer: files created to specifications need not be extensively “tweaked” on press.

A third theme is control. Tweaking and modifying presses to make non-standard files print properly costs time and money. In essence, such tweaking throws the process out of control. If file content conforms to guidelines, presses can be kept under control, makeready times can be shortened, and costs reduced. Control requires aim points: ink density, ink color, tonal value increase, print contrast, gray balance, print density curve, highlight-to-midtone range, and so on. Guidelines provide cooperating printers with such aim points.

## Which Guidelines Should Print Students Learn?

Instructors of print should procure, read, understand, and teach the basics of *all* printing industry guidelines. After graduation, students may obtain employment related to one or more printing industry segments. Thus, they should know SWOP for publications, GRACoL for commercial offset, SNAP for newspaper production, and FIRST for flexography. Lack of familiarity with one or more industry guidebooks could limit a graduate’s career options (R. Chung, personal communication, August 9, 2006).

The remainder of this paper reviews the file format guidelines recommended by the four industry associations and their impact on the print workflow. *Printing Industry Guidelines for Print Students Part Two: Printing Process Control and Color Separation* (Waite, submitted) covers the guidelines’ recommendations regarding both classic and colorimetric process control, color separation, and device profiling.

## File Format

When preparing pages for printing, designers generally use page layout programs to provide the structure and design for the job. Page layout files, also known as *native* files, vary in format from one program to another and gen-

erally do *not* contain photo or illustration files. Instead, graphic files are *linked* to the page layout file. In addition, page layout files do not contain the fonts used to display and output the typefaces used in the document. Thus, jobs delivered by a designer to a printing company or other service provider in the native format must be accompanied by both the fonts and image files.

The complexity of transferring native page layout files plus perhaps hundreds of additional support files (photos and fonts) that are required for a given job often leads to glitches during file output. To prevent such glitches, and to protect their equipment and revenue, printers have set up elaborate preflighting routines to catch errors at the onset of production. Even so, preflighting *catches* errors. It does not *prevent* them and may lead to animosity between printer and client.

To decrease the chance for error, all-encompassing file formats have been designed. These include TIFF/IT-P1 and PDF/X.

### *TIFF/IT-P1*

Manufacturers of computer electronic prepress systems (CEPS) developed the Tagged Image File Format/Image Technology, Profile 1 (TIFF/IT-P1) format to exchange files from dissimilar high-end prepress systems. These systems converted PostScript files into internal raster data prior to imaging them. TIFF/IT-P1 is an internationally-accepted format accredited by the International Standards Organization and known as ISO 12639:2004 (International Standards Organization, 2004). A TIFF/IT-P1 consists of three files: continuous tone (300 ppi), line work (1200–2540 ppi), and final layout file. Only CMYK or monochrome images can be included in a TIFF/IT-P1 set. All photographic and illustrative images as well as typefaces are incorporated into these files. Thus, there is no need to include fonts or linked graphic files with page layout files (SWOP Incorporated, 2005).

### *PDF/X-1a*

A second, and more widely adopted, all-inclusive file format relevant to the printing industry is based upon Adobe's Acrobat PDF format and is known as PDF/X-1a. Whereas TIFF/IT-P1 files contain raster data, PDF/X-1a files are object-oriented. A single file contains the page structure, text (including relevant fonts), photos, and illustrations. Instead of requiring fixed resolutions for graphic images, as do TIFF/IT-P1 files, PDFs can be created at varying levels of

quality depending upon the outcome intent of the document. For example, PDFs can be made specifically for computer-screen-viewing, desktop printer output, or printing press output.

A PDF/X-1a file is a specific type of printing press output PDF that contains all the criteria and content required to output a job using high-resolution printing presses. Thus, page layout files, linked graphics, and fonts do not need to be transmitted to the output provider or printer. A PDF/X-1a file: can only contain CMYK color, spot color, grayscale, or monochrome graphics; must contain all fonts required to output the job; does not allow for color management, transfer functions, or halftone screening specifications; and allows trapping to be included. Software programs used to create a PDF/X-1a file automatically enforce compliance with the format's specifications and will not allow the creation of a non-compliant file.

### *PDF/X-3*

Faculty should be aware that an additional print-specific PDF format—PDF/X-3—is currently in use throughout much of the world and that it is likely to be the next printing industry standard file format. In contrast to PDF/X-1a documents, PDF/X-3 files, “may contain data in color-managed color spaces (such as L\*a\*b, CalRGB or using an embedded ICC profile), and other data in grayscale, CMYK, and spot colors. The combination means that images can be included in a defined RGB space (for instance), while solid black text can be guaranteed to print in solid black without unexpected color fringing caused by color management spreading the black data to all the process separations” (Bailey, M., 2003). As the printing industry in the United States adopts color management and moves toward an RGB workflow, it is likely that the PDF/X-3 file format will supplant PDF/X-1a.

### *Printing Guidelines and File Formats*

SWOP *requires* that files be submitted *only* in the TIFF/IT-P1 or PDF/X-1a format. “The use of non-standard, application or native file formats is not allowed” (SWOP Incorporated, 2005). Although SWOP allows designers to save files in either format, a review of the specifications pages for numerous publications revealed that the trend is toward PDF/X-1a and *away from* TIFF/IT-P1. For example, see Time, Inc. (n.d.) *Specifications for Digital Ads*.

SNAP *recommends* the use of PDF/X-1a and recognizes the value of TIFF/IT-P1. As in the case of magazine publica-

tions, the trend in newspaper ads is toward PDF/X-1a and away from TIFF/IT-P1 and native files. For example, the *Houston Chronicle* accepts ads only in camera-ready hard copy form or as PDFs (Houston Chronicle, 2003).

GRACoL 6.0 (IDEAlliance, 2002) devotes nearly six pages to file formats and concludes by recommending native files for work in progress; PDF/X-1a, /X2a, or /X3a or TIFF/IT-P1 for file exchange within the graphic design studio and between designer and printing company; and PDF/X-1a, /X2a, or /X3a or XML for archival and repurpose.

Interestingly, FIRST is the most flexible of all the specifications. “It is not the purpose of FIRST to dictate which formats are to be used in the creation of flexographically reproduced artwork; however, it is highly recommended that digital artists understand the significant differences between the formats. The prepress provider is in the best position to describe the advantages and disadvantages of each format for a specific purpose” (Flexographic Technical Association, Inc., 2003). Even though the third edition of FIRST provides for some latitude in file formats, four pages (36–39) are devoted to PDF/X-1a.

## Recommended Instruction

Due to the overwhelming support for the PDF/X-1a format in current printing industry guidelines, it is recommended that print students be taught how to make these

files. Students must not only know *how* to make PDF/X-1a files, but also be *able to explain the process*. Most page layout programs can export documents in the PDF/X-1a format. However, the use of *Adobe Acrobat Distiller*, which creates PDF/X-1a files from PostScript print files made from native files, is the preferred technique. Students need to learn that native files should *only* be used for work in progress.

Once an instructor has made the decision to use a PDF/X-1a workflow in order to teach guideline-compliant printing, several changes to the curriculum must be made. In particular, preflighting, file intervention, imposition, and trapping processes must be PDF-friendly. The following paragraphs describe relevant software applications for these processes.

## Preflighting

To insure that files meet the requirements of the PDF/X-1a file format, students should be taught to preflight them before they are entered into the production workflow. After a PDF/X-1a file has been generated, Acrobat 7 can check it for compliance to the PDF/X-1a standard. The Preflight Window, accessible from the Print Production Toolbar, provides a list of PDF Profiles that can be used to check files (Figure 1). Note that the PDF/X-1a:2001 compliant profile has been chosen. If the Execute button is clicked, Acrobat 7 preflights the file and displays the errors it finds (Figure 2).

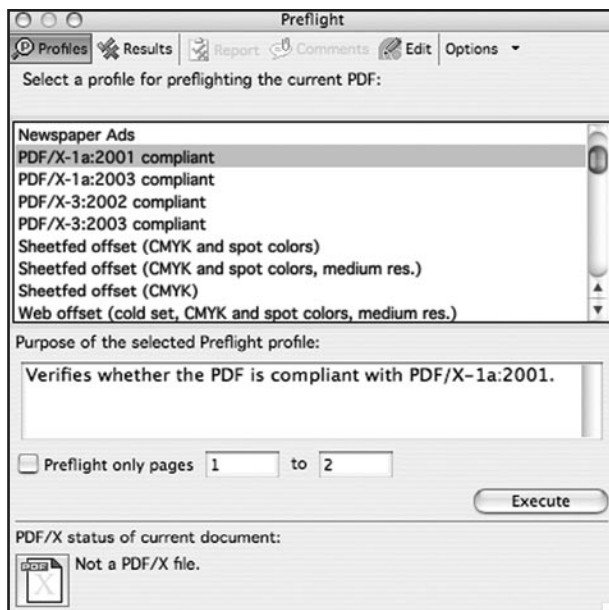


Figure 1 – Acrobat 7's Preflight Profiles window

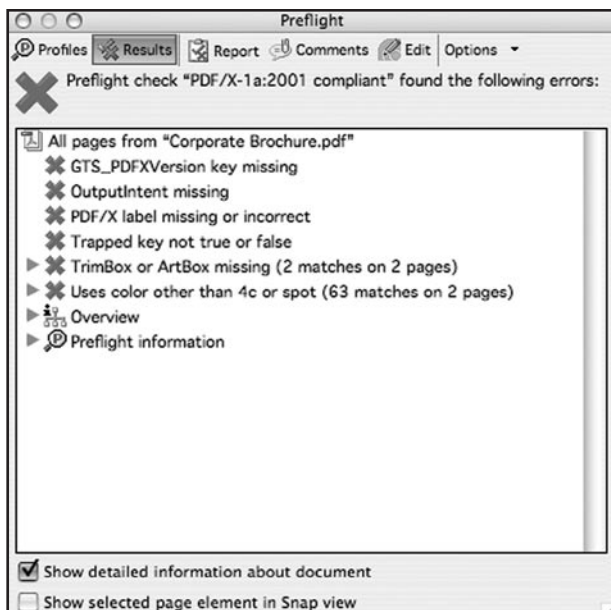


Figure 2 – Acrobat 7's Preflight Results window

More information about errors can be found by clicking the triangle at the left of items on the list.

Markzware's *FlightCheck Professional*, available from <http://www.markzware.com/>, can also check PDF/X-1a files for compliance. Figure 3 illustrates the Ground Controls window in *FlightCheck Professional*. Notice that the program has been instructed to insure PDF/X-1a compliance through the use of the Set popup menu at the top left. Clicking any of the buttons below the Set menu allows the technician to view the presets for other attributes of the document, such as pages, colors, and so on. Although presets, such as PDF/X-1a, cannot be altered (since they are defined by the appropriate standard itself), technicians can build and save other sets that will examine files on a more customized level. After a file that is not compliant with the PDF/X-1a standard is examined by *FlightCheck Professional*, the Results window

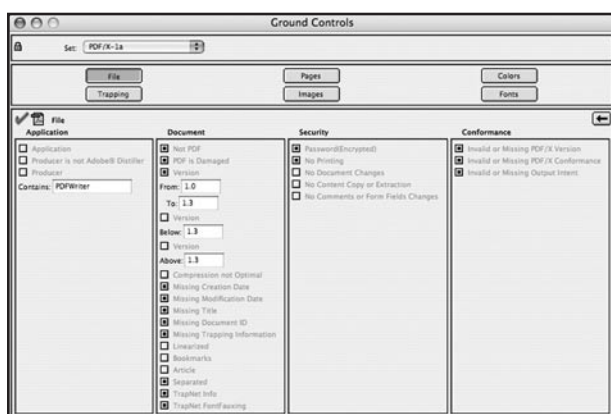


Figure 3 – *FlightCheck Professional*'s Ground Controls window

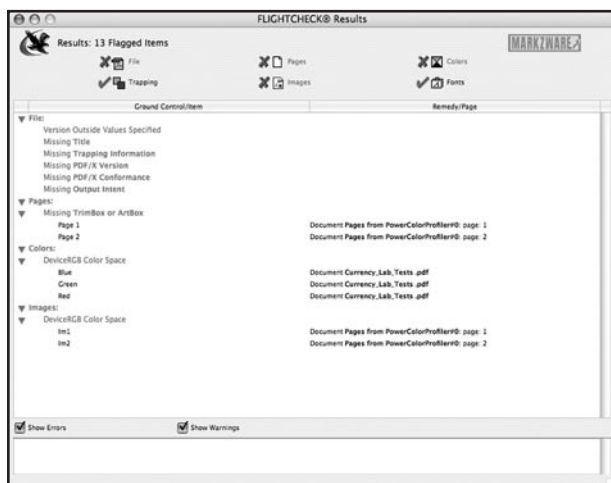


Figure 4 – *FlightCheck Professional*'s Results window

indicates, in red, those attributes of the tested file that are incorrect (Figure 4). In Figure 5, more specific information about the file is displayed. Non-compliant characteristics of the file, such as the RGB color space of Images IM1 and IM2, are flagged in red.

*PitStop Professional*, by Enfocus ([www.enfocus.com](http://www.enfocus.com)), is another program that can preflight PDF/X-1a documents. In addition, this software will certify that PDFs meet the PDF/X-1a standard. Figure 6 illustrates the *PitStop* PDF Profile Control Panel, which is accessible from Acrobat's Window menu after *PitStop* has been installed. If the PDF/X-1a:2001 Profile is selected from the scrolling list on the left and the Create Report button is clicked, *PitStop Professional* will repair as many defects in an open PDF file as possible and report any errors it cannot fix (Figure 7). Note that *PitStop Professional* fixed numerous errors in the file. However, since Baskerville Book Medium and Baskerville Book Regular were not installed on the host computer when *PitStop Professional* examined the file, those fonts could not be embedded. Similarly, *PitStop Professional* did not convert the RGB files to CMYK. (The *PitStop* Inspector can be used to remap RGB images to CMYK on an image-by-image basis

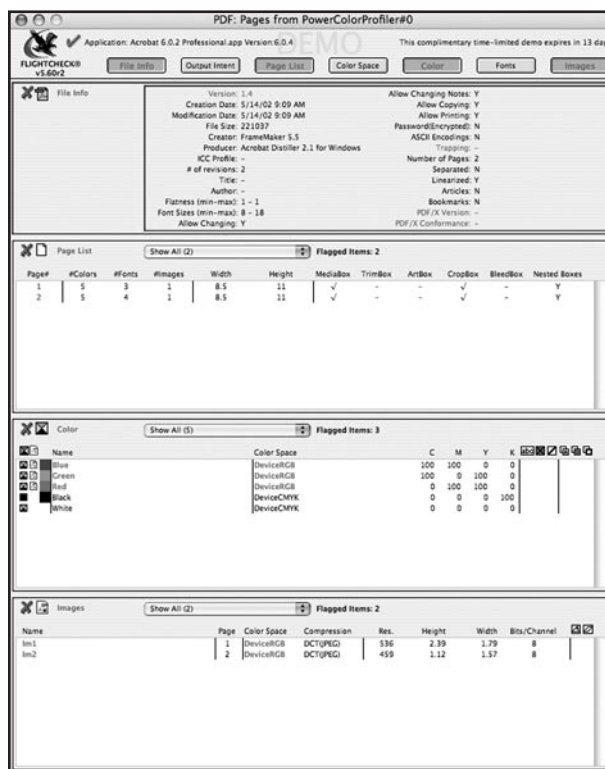


Figure 5 – *FlightCheck Professional*'s Page List window

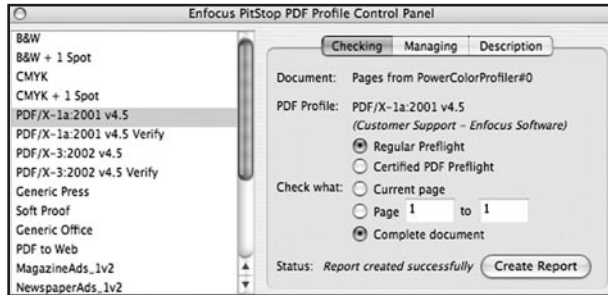


Figure 6 – PitStop Professional's PDF Profile control panel



Figure 7 – PitStop Professional's Errors & Warnings window



Figure 8 – PitStop Professional's Image Information window

or globally through the use of the PitStop Action List Control Panel.)

File attributes that *PitStop Professional* has examined are listed as links on the left side of the report form. Clicking a link causes specific information about that attribute to be displayed. In Figure 8, note that two images are in the RGB Color Space.

### File Intervention

If a PDF/X-1a file does not pass preflight inspection, the file must be remade or repaired. Such repairs are often called “file intervention.” In consultation with a representative of the printer, the client must decide who will repair or remake the file and how. The printer’s representative must be able to point out to the client what needs to be fixed and the cost of fixing it. The customer may then choose to make the repairs in-house or give permission to the printer to alter the file. If file intervention is to be conducted by the printer, prepress technicians must be able to fix the non-compliant PDF.

If a PDF/X-1a file is defective, the original native files can be repaired by the graphic designer and a new PDF/X-1a file generated. Alternatively, it is possible to repair many problems in PDF files by using specifically designed software.

One often-encountered problem in an otherwise useful PDF is the use of the RGB color space for images as well as text (non-graphics programs often build black text using red, green, and blue). A simple plug-in for Acrobat, *Quite a Box of*

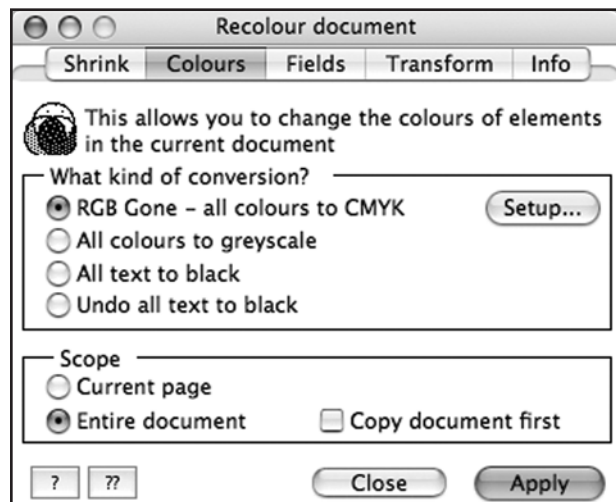


Figure 9 – Quite a Box of Tricks' Recolour document window

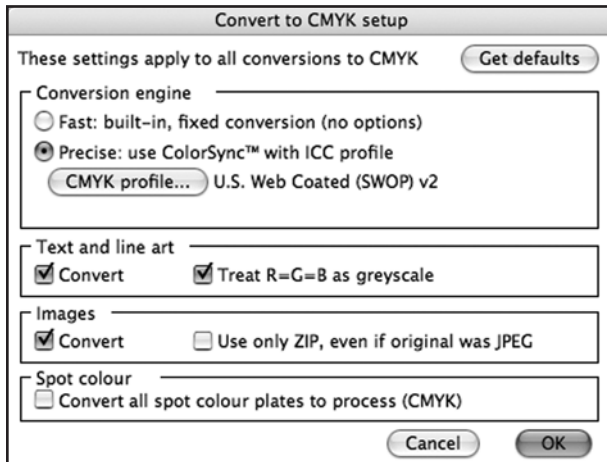


Figure 10 – Quite a Box of Tricks' Convert to CMYK Setup window

*Tricks* (available from [www.quite.com](http://www.quite.com)), can, among other useful functions, automatically convert RGB colors in PDF files to the appropriate ICC CMYK profile. After choosing *Quite a Box of Tricks* from *Acrobat's* Plug-Ins menu, the Recolour Document window appears (Figure 9). If the RGB Gone radio button is selected and the Setup button is clicked, the Convert to CMYK Setup dialog box appears (Figure 10). Selecting the Precise radio button and then clicking the CMYK Profile button allows the technician to choose the profile that corresponds to the applicable printing industry guideline. If the Treat R=G=B as Greyscale box is checked, any image created with equivalent amounts of R, G, and B (such as shades of grey or black), will then be converted to an appropriate K value. This eliminates black text and line art

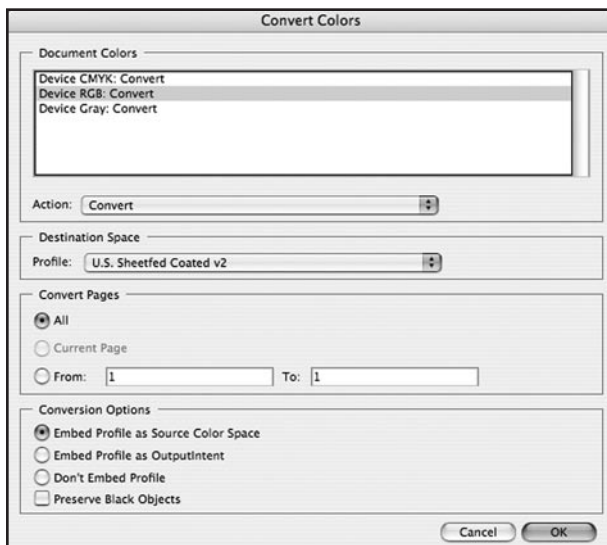


Figure 11 – Acrobat 7's Convert Colors window

builds. Conversion from RGB colors to the appropriate CMYK build occurs when the OK button and then the Apply button are clicked. If *FlightCheck Professional* is used to examine the converted document, no non-compliant colors will be flagged because all colors will have been transformed on the fly to CMYK.

*Acrobat 7* can also convert colors to CMYK using the Convert Colors dialog box, accessible from the Print Production Toolbar (Figure 11). Colors to be converted are chosen from the Document Colors scrolling list and then a Destination Space (U.S. Sheetfed Coated v2 in Figure 11) is selected. Clicking OK activates the conversion. *PitStop Professional* can also handle global color conversion to CMYK through the Action List Control Panel (Figure 12). The Convert Color to CMYK action is selected from the scrolling list and then the Execute button is clicked. The color conversion will be based on the parameters set on the Color Management tab in the *Enfocus PitStop Preferences* dialog box.

A PDF/X-1a file may be compliant with the standard yet still need to be changed or modified once the file has been received by the printing company. *Acrobat 7.0* allows a technician to make minor changes to an existing document. However, the tools within *PitStop Professional* are more robust. For example, *PitStop Professional* can change object colors, resample images, and change overprint settings and line weights. It can also be used to edit text—both horizontal and vertical—as well as paragraphs (additional text re-wraps). However, to edit text set in a particular typeface, the corresponding font must be installed on the computer used to make the changes.

## Imposition

Once PDF/X-1a files have been received, preflighted, and edited, they must be imposed so that their pages print in the

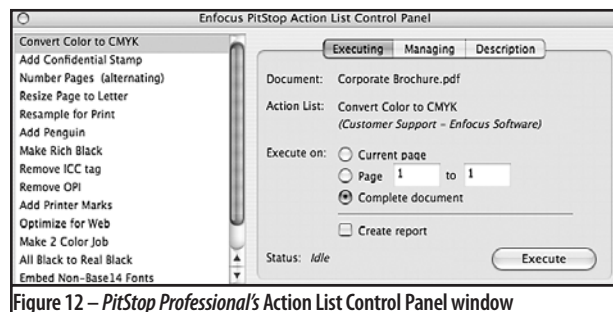


Figure 12 – PitStop Professional's Action List Control Panel window



proper order on press sheets. There are several programs that will impose PDF/X-1a files. Some work as plug-ins or XTensions to other programs (they reside within applications such as *QuarkXPress* or *Acrobat*) while others stand alone (they require no host program). In the first category, Dynagram's *INposition* (<http://www.dynagram.com>) is an XTension for *QuarkXPress* that will impose PDF files as well as *QuarkXPress*, *PageMaker*, and *InDesign* native files and EPS, TIFF, PICT, and PostScript files. Similarly, *Quite Imposing Plus 2* ([www.quite.com](http://www.quite.com)) is a plug-in for *Acrobat*. Like *Quite a Box of Tricks*, *Quite Imposing Plus 2* is accessed

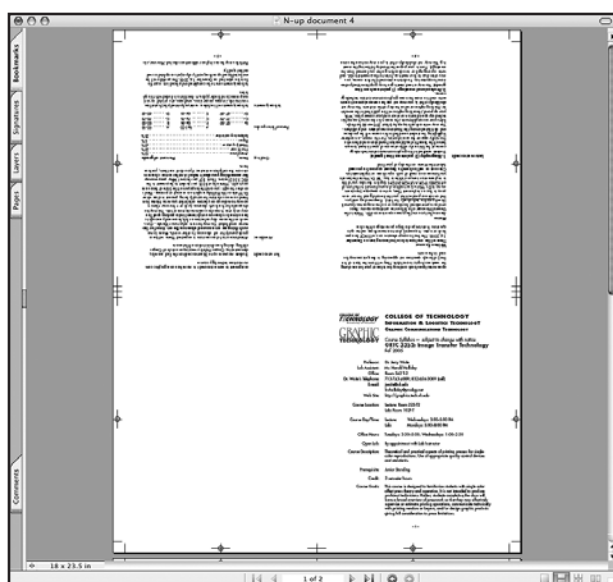


Figure 13 – *Quite Imposing Plus*' Control Panel window

through the Plug-Ins menu in *Acrobat*. Figure 13 illustrates the Control Panel window. To make an eight-page sheetwise imposition, the pages must first be shuffled to match the order in which they will appear on the press sheet. If the Shuffle Pages button, in the Page Management section, is clicked, a series of windows appears to guide the user through the shuffling process. Once the pages are shuffled, the pages are imposed using the N-Up Pages button. Again, a series of windows appears to assist in creating the appropriate imposition. An example of the front of a finished eight-page imposition is shown in Figure 14. Note the trim and register marks that have been included by the software and that previews of the actual pages are shown.

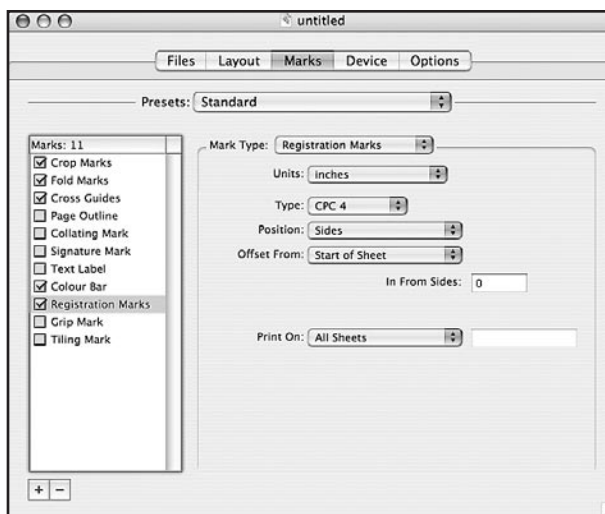


Figure 15 – *Imposition Publisher's* Control window

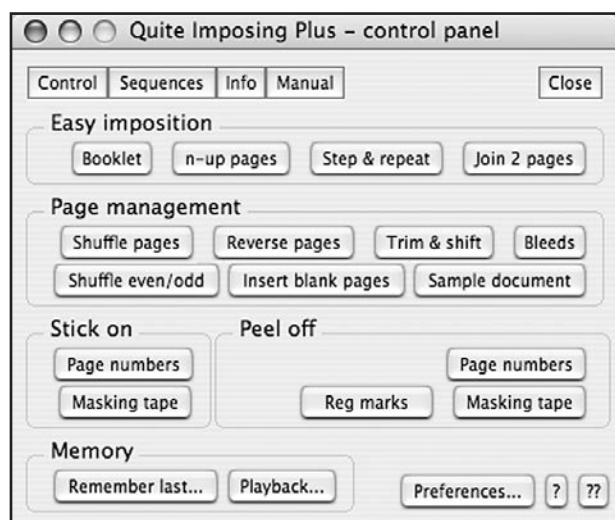


Figure 14 – The front of an eight-page signature created with *Quite Imposing Plus*

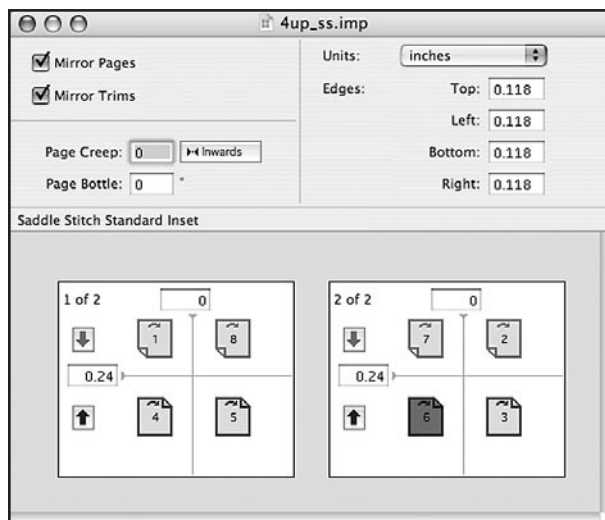


Figure 16 – *Imposition Publisher's* Four-up Sheetwise Imposition window

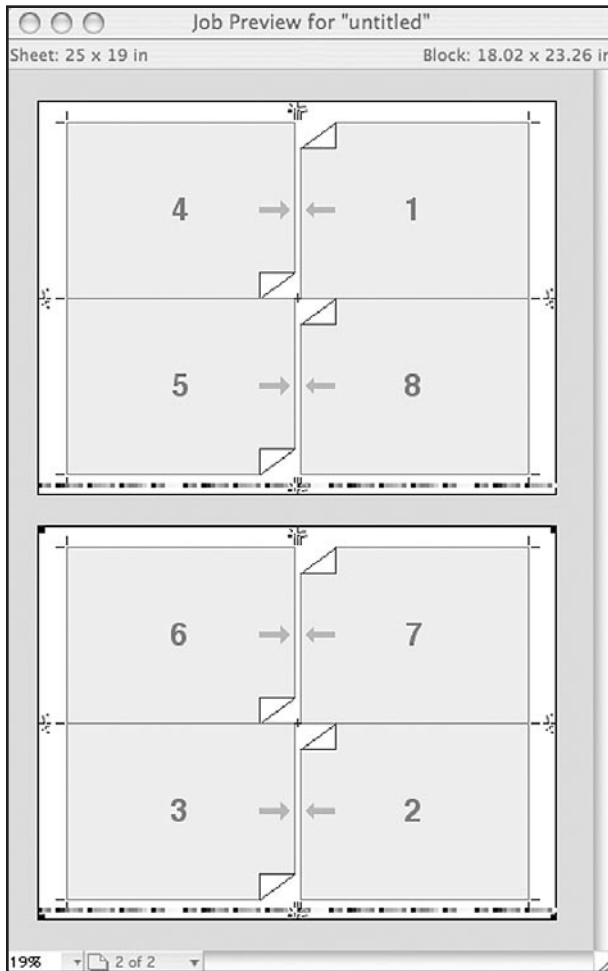


Figure 17 – *Imposition Publisher's* Job Preview window

Unfortunately, the addition of color bars is not automatic and requires the user to create, define, and use a background when the imposition is output. Instructors and professors who prefer to teach manual imposition will like *Quite Imposing Plus 2* because it requires the student to make an imposition dummy to use as a guide while shuffling the pages and creating the imposition.

*Imposition Publisher*, from Farrukh Systems LTD ([www.farrukh.co.uk/](http://www.farrukh.co.uk/)) is a stand-alone program that uses templates to quickly impose PDF files. When *Imposition Publisher* is launched, a control window is displayed (Figure 15). This window is used to add files to be imposed, select the appropriate template and marks, set page size and scaling, and choose appropriate options. Once a template is chosen, a window bearing its name appears (Figure 16). This window is used to set the trims, margins, and creep. The Job Preview window (Figure 17) displays a sample of the finished signatures. Note that trim marks and color bars are previewed, but page content is not.

In addition to imposing PostScript files, *Preps* ([http://graphics.kodak.com/us/product/workflow\\_data\\_storage/production\\_planning/preps/default](http://graphics.kodak.com/us/product/workflow_data_storage/production_planning/preps/default)) can also impose PDF/X-1a files. Figure 18 illustrates the front of a 16-page signature created from multiple PDF files as it is displayed in the Preps Preview: Signature List window. In Figure 19, three flats from a 32-page PDF booklet created by *Preps* are shown in an *Acrobat 7* window. Note that, in both illustrations, color bars, marks, and page content are clearly displayed. Faculty who wish to teach students to impose PDF as well as PostScript files may wish to consider *Preps* instead of the

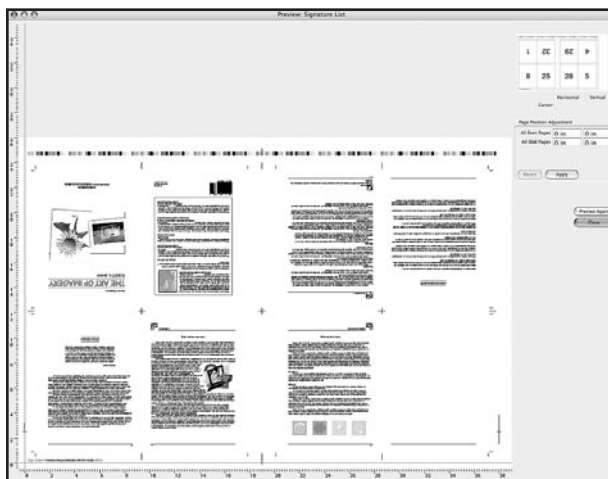


Figure 18 – The Front of a 16-page signature created by *Preps*

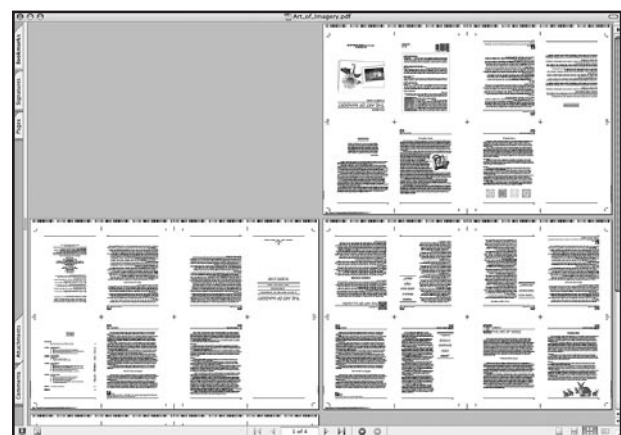


Figure 19 – Three imposed flats created by *Preps* as shown in *Acrobat 7*

other programs mentioned in this paper because it can impose files in formats other than PDF.

## Trapping

Trapping is one area in which the printing industry guidelines disagree and contradict each other. Since PDF/X-1a is the preferred or specified method of exchanging documents, and since PDF/X-1a files may include trapping (trap flag = “TRUE”) or not (trap flag = “FALSE”), confusion—and errors—can easily occur. SWOP specifies: “All supplied materials sent to the publisher or printer must be properly trapped and, when possible, image trapping should be represented in the accompanying SWOP proofs” (SWOP Incorporated, 2005). Therefore, the graphic designer is responsible for creating traps in documents prepared for publication printing. Similarly, SNAP assumes that the designer will trap all images since its trapping specifications are in its “Design Guidelines” section (Newspaper Association of America, 2000). FIRST is ambivalent about trapping, listing trap specifications in both its “Design” and “Prepress” sections. Finally, GRACoL 6.0 advises the designer to refrain from trapping: “Do this only if you understand the parameters of the job. The best advice is to consult the printer before you attempt to trap colors because the proper amount of trap

varies from printer to printer and from press to press” (IDEAlliance, 2002).

With the introduction of *Acrobat 7*, in conjunction with PostScript Level 3 RIPs, trapping is becoming much less of an issue than it has been in the past. *Acrobat 7*’s Trap Presets window (Figure 20) allows the technician to apply trap settings to a page or range of pages in a PDF file. *Acrobat* comes with a default Trap Preset. However, customized trapping scenarios can be created by clicking the Create button on the Trap Presets window to display the New Trap Preset dialog box (Figure 21). The settings in the New Trap Preset dialog box are similar to those used in other design and prepress programs and can be used to set all the parameters of trapping, including join style, end style, trap placement, and so on. Trap Presets does not physically trap the open document. Instead, it provides a series of instructions that instruct a PostScript Level 3 RIP how to handle traps during output.

Since all four printing industry guidelines recommend or specify the use of the PDF/X-1a format for file exchange, students of print should be taught how to set traps in *Acrobat 7* as well as in page layout, illustration, or pixel-editing software. Trap-annotated PDF/X-1a files should then be output to film, plate, or digital press using in-RIP trapping that is based on the parameters chosen in the Trap Presets dialog box.

It is further recommended that, given the trapping capabilities of *Acrobat 7*, the SWOP, SNAP, FIRST, and GRACoL committees instruct graphic designers to refrain from trapping files. Using *Acrobat 7*, in conjunction with PostScript Level 3 RIPs, to specify traps during output will allow last-minute changes in trapping parameters to be made on a completed and imposed PDF/X-1a file prior to output.

## Other Guidelines of Importance to Print Students

SNAP, GRACoL, SWOP, and FIRST all provide numerous other guidelines of importance to graphic design and print production. Those particularly important to graphic designers are highlighted in a companion piece to this article entitled *What to Teach Graphic Design Students About Printing Industry Guidelines* (Waite, 2006). Another related paper, *Printing Industry Guidelines for Print Students Part Two: Printing Process Control and Color Separation* (Waite, Submitted) highlights process control methods recommended by the



Figure 20 – *Acrobat 7*’s Trap Presets window

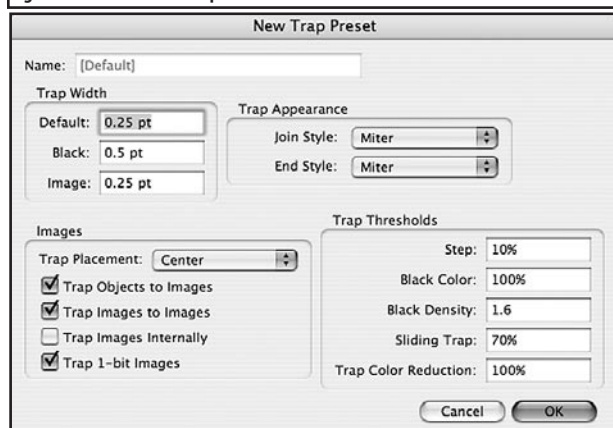


Figure 21 – *Acrobat 7*’s New Trap Preset dialog box

guidelines and how process control impacts color separation techniques. Nonetheless, since printing industry guidelines define the parameters for our industry, it is imperative that print instructors and professors procure and teach the guidelines relevant to the careers their students will follow.

## Implications and Recommendations

This paper, along with its companion pieces, has highlighted a few of the guidelines recommended by printing industry groups. The guidelines underline an undeniable shift in the responsibilities of both graphic designers and print production personnel. Whereas printing company technicians used to *create* documents in a closed-loop environment, they are now expected to *process* documents created by graphic designers. In effect, printing companies have lost a good deal of control of the process because their employees do not create documents, scan images, or perform color separations. Instead, those operations are performed off-site.

To introduce some order into the process, printing industry groups offer guidelines. Some of those guidelines focus on file formats and document transfer. In particular, the adoption of the PDF/X-1a (and eventually PDF/X-3) format seems to be inevitable. The consequences of this PDF-centric workflow are widespread and force printers to implement software solutions to deal with PDF preflighting, trapping, editing, imposing, and RIPping. In addition, due to the CMYK-only nature of PDF/X-1a files, printers not only have to calibrate their presses and measure their characteristics, but also *keep their processes under control*. These are challenges that must be met if printers are to stay competitive.

Students of print must be prepared to meet the challenges of the world of the printing and publishing industry, *as it exists now and in the foreseeable future*. Thus, instructional programs must change. Gone are the days when students could spend a majority of their time learning to create page layout files, create vector- or pixel-based images, and output to a laser or ink-jet printer. Yes, they need to know the basics of those processes so that their knowledge can provide added value to the company's sales force. However, the focus must be on successfully outputting PDF/X-1a (and eventually PDF/X-3) files using a workflow that is process controlled.

Faculty are challenged to create curriculums that, while respecting the importance of page layout and image

manipulation, emphasize a thorough understanding of the PDF/X-1a (and eventually PDF/X-3) workflow along with practical experience in measuring and controlling the printing process. This may require fundamental shifts in the way courses are taught, the way laboratories are arranged, and the software employed. By way of example, one common pedagogical practice that may need to be changed is the amount of time spent in print technology classes learning tasks that are essentially within the realm of the contemporary graphic designer.

Textbook publishers and authors are challenged to provide books that can be used by graphic arts teachers and instructors who wish to teach guideline-centric courses. For example, can an enterprising author come up with a way to teach students to measure and control the often low-end equipment that exists in most graphic arts classrooms? Or, can a textbook publisher commission a book that teaches PDF/X-1a workflow from file acceptance through preflighting, editing, imposing, trapping, and RIPping?

## Conclusion

National and international associations have standardized many of the variables inherent in various printing processes and have codified their recommendations into guidebooks such as SNAP (newspaper production), GRACoL (commercial printing), SWOP (publications printing), and FIRST (flexographic printing). If students of print are to be effectively prepared for careers as sales support personnel, managers, or technicians, they must know and be able to implement the contents of the appropriate guidebook. This literature review has introduced SNAP, GRACoL, SWOP, and FIRST and highlighted file format considerations and techniques that print students *must know*. To be truly effective, instructors, students, and practitioners should obtain each of the guidebooks and review them carefully.

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# Barriers to the Successful Implementation of Print Management Information Systems (Print MIS) in Midsize Commercial Printing Companies: A Qualitative Study

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## Introduction

In today's commercial printing industry, there are growing internal and external pressures to implement more up-to-date digital process systems to remain competitive. The Print Industries Market Information and Research Organization (2005) found that only 53% of the 16,000 commercial printing plants that are of a size to benefit from a fully integrated Print Management Information System (Print MIS) have one installed. Most of those that have installed Print MIS cannot follow an integrated methodology with an electronic, on screen, job ticket because their estimates fail to consider all their production operations. Many use estimating modules extensively but supplement them with spreadsheets for pricing specialized functions (i.e., digital prepress, digital printing, finishing, and mailing). Thus, fewer than 10% of printing companies have implemented computer-assisted scheduling even though they own the module.

The print industry has evolved to a predominantly digital workflow which includes applications of Computer Integrated Manufacturing (CIM) and Job Definition Format (JDF). While it would seem that this digitally advanced environment might present an ideal opportunity for the efficient use of Print MIS, certain factors inherent in commercial printing pose some formidable barriers to its successful implementation and utilization.

Goldman (2003) observes that the majority of Print MIS users fail to exploit its full potential for serving their various needs. According to Muscatello, Small, and Chen (2003), although a fair amount of data is available on the successful implementation of Enterprise Resource Planning (ERP) systems in large corporations, relatively little data exists about MIS use in small to midsize manufacturing firms. ERP are larger systems, mostly targeted for large corporations (including multi-nationals), and include operations modules with a focus on marketing and business strategy as well as human resource and cross organizational issues (Esteves & Pastor, 2001). Print MIS, a simpler system, is intended for midsize commercial printing companies and primarily focuses on operations (e.g., the integration of production

scheduling, accounting, inventory, billing, and so on). Muscatello et al. (2003) urge the need for further research and dissemination of data on how midsize organizations can more effectively and profitably incorporate MIS technology to meet their specific needs. A freer flow of reliable data on appropriate Print MIS application in midsize commercial printing companies is, therefore, a matter of timely concern. Thus, my aim in this study was to explore how the larger body of available data on the successful implementation of ERP systems in large corporations might apply to understanding the barriers involved in the installation of Print MIS in midsize printing companies.

## Need for the Study

This qualitative, exploratory study has added to our knowledge on how key industry experts perceive the importance of previously identified factors critical to the successful implementation of Print MIS in midsize commercial printing companies. Furthermore, it has made an important contribution to the existing body of literature by bringing to light additional factors that experts identified in the study as playing a significant role in Print MIS implementation.

## Purpose of the Study

This qualitative, exploratory study explored the relevance of critical factors for the successful implementation of Print MIS in midsize commercial printing companies and why they are perceived to have difficulty with implementing such technology. Specifically,

1. How do previously identified factors critical to the successful implementation of ERP systems in large corporations relate to the successful implementation of Print MIS in midsize commercial printing companies, as perceived by key personnel in the printing industry?
2. What other factors critical to the successful implementation of Print MIS in midsize commercial printing companies are identified by key personnel in the printing industry?

In-depth, one-on-one interviews allowed the expert participants to more openly discuss their operations than would have been possible via a more impersonal quantitative survey instrument. The in-depth interviews provided rich and detailed information about their perceptions of decision-making processes and of the impact of pricing pressures.

## Related Literature

Based on their research, Markus and Tanis (2000) identified four phases in the ERP life cycle: (1) Chartering: Defining the business case and solution restraints; (2) Project: System configuration and rollout; (3) Shakedown: Fine-tuning and de-bugging for normal operational use; and (4) Onward and Upward: System maintenance and support, upgrading, and user skill-building. Nah, Lau, and Kuang (2001) attempted to uncover the critical factors associated with the high failure rate of ERP implementation. A computer-based search located ten relevant articles on information systems. An analysis of these articles revealed 11 factors critical for the successful implementation of ERP systems: (1) ERP teamwork and composition; (2) change management program and culture; (3) top management support; (4) business plan and vision; (5) business process reengineering (BPR) and minimum customization; (6) effective communication; (7) project management; (8) software development testing and trouble-shooting; (9) monitoring and evaluation of performance; (10) project champion; and (11) appropriate business and IT legacy systems. Nah et al. (2001) then applied their 11 critical success factors to Markus and Tanis's four sequential phases and determined that seven of the 11 factors were applicable in phase 1 (namely, factors 1, 3, 4, 6, 7, 10 and 11), indicating that the majority of factors crucial to success must be addressed during the first phase of implementation, such as Chartering, and that success or failure is likely to be determined long before the system configuration and roll-out phases of the process.

## Method

This qualitative study involved in-depth interviews with industry experts regarding their perceptions of how the successful implementation of ERP systems in large corporations related to the implementation of Print MIS in midsize commercial printing companies. A semi-structured format of open-ended questions with in-depth follow-up discussions was used in the interviews.

The sample included three expert participants in the U.S. Commercial Printing Industry with broad-based knowledge of Print MIS implementation in the industry. All three participants are based in the North East, but have extensive national experience. The first participant was a systems implementation consultant, male, with more than 35 years experience; the second participant was a veteran printing industry person, female, with more than 20 years experience; and the third participant was a systems vendor, male, with 20+ years experience.

The interview guide was based on Markus and Tanis's (2000) theoretical work on the four phases in the ERP life cycle and Nah et al's (2001) research on the 11 factors critical for successful implementation of ERP systems. The questions focused on the three participants' perceptions of Nah et al's critical factors and their relationship to the four phases in the ERP life cycle. The questions were also geared to elicit their perceptions of additional factors relevant to the successful implementation of Print MIS in the printing industry. For example, Holsapple, Wang, and Wu (2005) found that with respect to ERP success, "higher-educated users have greater user satisfaction and managers have greater satisfaction than non-management users" (p. 333). The interview guide was reviewed by a four-member jury of experts: a university professor with expertise in questionnaire development and survey research; two university professors of computer science/management information systems; and one senior graphic communications executive familiar with Print MIS applications and automation in the industry. Each interview lasted two to three hours and took place between October 2005 and March 2006.

## Results

Although not familiar with Nah et al's (2001) 11 critical factors, the three interviewees unanimously found them to be very relevant regarding barriers to Print MIS implementation in midsize commercial printing companies. The interviewees also identified additional factors—for example, barriers, such as competitiveness, lack of education/management training, and demands for customization. Using a three-point scale (3 = a major impediment), each expert categorized the 11 critical factors in terms of their degree of importance as an impediment—Major, Moderate, or Minor—to the successful implementation of Print MIS in graphic communications companies. Factor ratings were then totaled: those scoring between 8 and 9 were categorized as a major impediment; between 5 and 7 a moderate impedi-



ment; and between 3 and 4 a minor impediment. The factors within each of the three categories of degree of impediment are presented below:

## Major Impediments

- **ERP Teamwork and Composition.** Thin profit margins lead to lean staffing, making it difficult to free up key staff people from operational roles so that they can dedicate their time to a long-range multifaceted project.
- **Top Management Support.** The industry's highly competitive nature leads executives to focus more on financial performance or sales and shirk from dedicating necessary resources or risking workflow interruptions, both of which are necessary for a Print MIS installation successful.
- **Business Plan and Vision.** A lack of strategic planning, the reluctance or inability to commit major resources (dollars, time, and people); the tendency to concentrate on individual areas and not see the "big picture."
- **Business Process Reengineering and Minimum Customization.** An unwillingness to reengineer operations to accommodate the new Print MIS. Instead, many express the desire to have a Print MIS conform to their way of doing business.
- **Effective Communication.** Information does not flow smoothly from executive managers to production workers; and lean staffs force key personnel to wear many hats. This limits the amount of time the executive managers spend on communicating.
- **Project Management.** Even though the organizational culture may be team-oriented, a lean workforce makes it difficult to spare people for work on a dedicated system installation project.
- **Appropriate Business and IT Legacy Systems.** A widespread unwillingness to depart from the use of legacy systems within individual areas, both production and office, coupled by the inability to free up funds to replace or modify existing systems.

## Moderate Impediments

- **Change Management Program and Culture.** The management of most commercial printing companies

accepts the need for change, but employees may be resistant to change because they are wedded to familiar practices.

- **Project Champion.** The project champion is often not high enough on the management chart to command the respect and authority necessary to bring all areas on board and make them committed to its success. The lean staffing makes it difficult to free up high-level managers to champion the project or add it to their duties.

## Minor Impediments

- **Software Development, Testing, and Troubleshooting.** Systems can be put in place if individual areas are willing to let go of their legacy systems.
- **Monitoring and Evaluation of Performance.** Despite workflow pressures, the monitoring process is not intrusive if the commitment to Print MIS installation has been made.

As Table 1 indicates, seven of Nah et al.'s (2001) 11 critical factors were perceived to be major impediments to the implementation of Print MIS within the printing industry, two as a moderate impediment, and another two as a minor impediment. Of the seven viewed as "major" stumbling blocks, six apply to key management vision, support, commitment, and project oversight areas that play a crucial role in getting Print MIS projects on the company's radar screen in the first place. In addition, virtually all are directly related to the limited resources available to midsize printing companies that operate in a highly competitive industry with historically thin profit margins.

## Additional Industry-Specific Variables

The experts also added to Nah et al.'s critical factors some variables specific to the midsize commercial print industry that they believed played a significant role in the successful implementation of the Print MIS process. These included:

1. **Competitive Challenges:** Since the commercial printing industry is extremely competitive, printing companies have little incentive to invest in systems that appear to overlay the actual printing process without adding immediately perceptible value to the final product. As a result, management is skittish about introduc-

ing a system that might interrupt the workflow or create an unacceptable degree of downtime as a new system is installed and workers are trained in its use. Management is also reluctant to undertake trying to implement any system that might pull their best people off the production floor, involve large investments (with many hidden future costs), especially with the possibility that the new system might engender unpredictable results.

2. **Lack of Professional Management Training:** In many midsize commercial printing industry companies, the level of management training is not at the same level as that found in major corporations implementing ERP systems. This is apparent in the frequent lack of business vision and in the failure to create a culture that is receptive to or conducive to change.
3. **Customization:** Virtually all commercial printing work involves some degree of customization and the environment is less predictive of what future projects might entail. Therefore, companies are less receptive to an overall management system more suited to a repetitive and predictable workflow. At any given time, the number of variable factors in any print job is immense. Furthermore, even once work has started on a project, changes often continue to occur during the manufac-

turing process as the customers' needs change or they find it necessary to make unanticipated alterations to the desired end product. This, necessarily, requires even greater investments to tie the disparate systems together in an over-arching Print MIS architecture.

4. **Job-Shop Environment.** Although commercial printing is essentially an assembly line of successive segments, it is a job-shop manufacturing process rooted in a craftsmanship environment. Thus, despite the introduction of computerization and digitization into nearly every element of the process over the last two decades, it still comprises individual units with discrete production steps that maintain a "pride of ownership" approach to their segments of the overall job. This often leads to "turf battles." Further, the situation is exacerbated when management introduces a system that will coordinate and integrate all facets of the production and billing process.

## Conclusion

While the competitive nature of the commercial print industry provides some impetus for the full utilization of Print MIS, it presents an even more compelling impediment to its successful implementation. Tight profit margins can make it very difficult to free up the capital and staff resources

Critical Factors in Implementation of Print MIS	Degree of Importance as an Impediment		
	Major	Moderate	Minor
1. ERP teamwork & composition	X		
2. Change management program & culture		X	
3. Top management support	X		
4. Business plan & vision	X		
5. Business process reengineering (BPR) & minimum customization	X		
6. Effective communication	X		
7. Project management	X		
8. Software development testing & trouble-shooting			X
9. Monitoring & evaluation of performance			X
10. Project champion		X	
11. Appropriate business & IT legacy systems	X		

Table 1—Interviewees' Rankings of Critical Factors: Their Degree of Importance as an Impediment to the Successful Implementation of Print MIS in Graphic Communications Companies

needed to properly incorporate MIS technologies. Some of the other impediments seem, on the surface, to be more people rather than resource based—from the unwillingness of top management to make a total commitment to the new technology at the strategic level, to the unwillingness of line workers to adapt to new ways of doing work and letting go of their traditional work practices. In reality, in such highly competitive, tight profit environments, financial pressures tend to keep staffing at a functional minimum, to free up either management or staff to take on new tasks and still keep the production line moving, and render management loathe to jeopardize actual cash flow from existing work while they seek to successfully add new systems that offer possible future enhancements.

## Implications of this Study for the Midsize Commercial Print Industry

Midsize companies cannot allow the above-mentioned barriers and the industry's competitiveness to hinder the implementation of Print MIS, because, in fact, well-integrated and implemented Print MIS would help them to be more competitive.

1. Companies should first attend to a successful Print MIS implementation before moving on to new Job Definition Format (JDF) and Computer Integrated Manufacturing (CIM) systems.
2. An experienced consultant with a strong background in Print MIS should be included in at least the initial chartering and project stages of the implementation of such systems.

## Suggestions for Future Research

This exploratory study's results point to directions for future research, as follows:

1. This exploratory study examined key industry experts' perceptions about Nah et al's (2001) previously identified critical factors as well as the additional factors identified by these same experts as significant to Print MIS implementation in midsize commercial printing companies. Can the qualitative results of this exploratory study be supported by those obtained from a more broad-based, systematically-designed quantitative study of midsize commercial printing companies?

2. Future research on such commercial printing communication segments as large commercial printers, packaging, and special process printing (e.g., gravure, flexography, digital printing) might help to determine if the findings of the present study can be applied industry-wide.
3. Further research on MIS implementation within other types of job shop highly competitive businesses might help to clarify the role of competitiveness in this process as well as reveal additional relevant factors that might also apply to the commercial printing industry.

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# The IDEaLaboratory: A Concept in the Making

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## Introduction

Because technology is socially, culturally, economically, and politically constructed by our society, technology changes our society and our lives. Both informed decision-making in a democratic society and the economic health of the United States are dependent on managers and workers who are innovative and creative thinkers and who address ethical issues. The creative application of technology to solve problems impacts the life of the American consumer by its effect on the economy.

Global businesses need employees who know how to think and solve problems inventively in order to produce economic results. Sustainable economic growth is dependent upon innovative technological application and organization of technical systems in businesses. Strategic employees in the 21st century are innovative thinkers, who understand how to apply problem-based learning with “out-of-the-box” approaches in an organization.

One approach to out-of-the box thinking is problem-based learning (PBL), which is based on the idea that learning is initiated by identifying a real-world problem (Duch et al., 2001). Students are motivated to discover solutions to problems through group questioning and evaluation. This methodology of progressive disclosure (Barrows and Tamblyn, 1980) has the characteristics of scholarly inquiry through critical thinking. The IDEaLaboratory at Arizona State University proposes to take problem-based learning and enhance its value through groundbreaking thinking and learner-centered activities.

The IDEaLaboratory is a response to the growing concern that students at all levels are merely being taught to pass tests and are, therefore, becoming successful at memorizing factual information and delivering packaged answers. In order to learn how to take an original approach in solving problems, one must learn how to think inventively, often bringing about more questions than answers. The good news is that novel thinking, both creative and critical, can be developed and enhanced when threaded throughout university disciplines.

Literature on pioneering strategies of thinking is plentiful, ranging from books on business and industry (Tanner, 1997)

to books focusing on the creativity process and creative problem solving (Harris, 1998; von Oech, 1986, 1990; Isaksen et al., 1998; Csikszentmihalyi, 1996; Buzon, 1983; Gardner, 1983; Glassman, 1991; Higgins, 1994; Osborn, 1979; Parnes, 1992). The Canadian Conference Commission’s Innovation Skills Profile (CBC, 2005) lists more than 50 different innovation skills. Other studies identify additional innovation skills (Christensen, 1997; AG, 2005; Taylor, 2005; de Bono, 1971, 1985, 1990, 1990, 1992, 1994, 1995, 2005). Literature has been written on strategic thinking focusing specifically on engineering and technology (Altshuller, 1984, 1990, 1997; Fogler, 1995; Sickafus, 1997, Lumsdaine and Lumsdaine, 1995; Raviv, 1999). In order to provide the most beneficial curriculum, specific hands-on, first-hand knowledge must be utilized for a rich cross-disciplinary experience.

## What is Creative and Innovative Thinking?

If one learns to generate new ideas by reapplying, reorganizing, and revising today’s ideas in a new way, innovation is born. The National Innovative Initiative’s 21st Century Working Group Report, which was delivered to President Bush in December 2004, defined innovation as “that which transforms insight and technology into novel products, processes, and services creating new value for stakeholders, driving economic growth and improving standards of living” (NII, 2004).

This kind of creative attitude is open to possibilities, accepting of change, and continually striving for improvement. Creative thinking is “to cause to come into being, as something unique that would not naturally evolve or would not exist via ordinary processes, resulting from originality of thought” (Idea Champions, 2005). Creativity is an ability, attitude, and a process (Harris, 1998).

With practice and a renewed sense of shedding suppressive learned behavior, everyone is capable of thinking creatively and innovatively. To improve creative thinking, one must learn how to accept change, be more flexible, be more playful with possibilities, be appreciative of the good things in life, and always want improvement.

Creative thinking is a right-brain activity diffusing one of the many solutions to a problem through subjective associative innovation. Creative thinking is used to generate and suspend judgment on possibilities, usually through visual means, by completing the statement “Yes, and ...” The creative thinker’s lateral thinking is divergent (Harris, 1998) and is concerned with seeking as many different approaches as possible in order to change concepts and perceptions (de Bono, 2005).

It is also significant to identify the differences between critical and creative thinking. Critical thinking is a left-brain activity that focuses on obtaining the solution to a problem through objective linear reasoning. Critical thinking is used to analyze and critique probability, usually orally, by completing the statement “Yes, but ...” The critical thinker’s vertical thinking is convergent (Harris, 1998). It looks to the right approach, is analytical, and sequential. Problem-based learning is an approach to critical thinking, and both types of thinking are used in the IDEaLaboratory at Arizona State University. In the IDEaLaboratory, the creative thinking process is used to generate new ideas and embrace PBL with an innovative approach. The critical thinking process is used for critiquing solutions and project assessment.

## Obstacles to Creative and Innovative Thinking

Some patterns of behavior erect obstacles to creative and innovative thinking. These obstacles lead to repressed thinking. The obstacles that are particular to an organization and an individual need to be identified in order to form a healthy foundation for inventive problem solving. They can be simplified into the following categories: (1) attitude, (2) failure, (3) Polly Anna Syndrome, (4) industry leadership, (5) human factors, (6) inventive thinking training, and (7) organizational vision.

### *Attitude*

There is an Asian symbol for crisis that many believe is the same symbol for danger plus opportunity (Headley, 2003), although some dispute the old cliché (Pinyin.info, 2005). When faced with a problem, look at it as being confronted with an opportunity. Holding up the white flag before you begin is a self-fulfilling prophecy. The world is full of skeptics and they have their role as devil’s advocate

in problem solving. But without being open to all the possibilities, no imaginative innovation will occur.

If creative thinking appears childish or beyond your personal reach, think again. If problem solving appears to be out of your realm of expertise, think again. The Wright brothers, inventors of the airplane, were bicycle mechanics, not aviation engineers (Eppler, 2003). Kodachrome was invented by two musicians—Leopold Mannes and Leopold Godowsky, Jr. (wikipedia.com, 2006).

Just as innovations are socially constructed, so is our socially accepted behavior to conform to the norm. To be a creative thinker is to think differently from the ordinary and not to worry about what people will think about you. A creative thinker is willing to challenge the status quo.

### *Failure*

There is nothing wrong with failure and making mistakes in spite of what the American society believes. It is a sign of action and risk-taking. It opens up opportunities. One of the most significant obstacles to unleashing the creative juices to solve problems is the fear of failure. Much knowledge for future success can be gained from failure. An organizational culture of fear results in risk aversion in which criticizing how things are done becomes a high-risk activity for job stability.

Fear of hard work and not being persistent are obstacles to creative thinking and problem solving. It takes time and energy to solve problems. It takes time and skillful brainstorming facilitation to develop new ideas.

### *Polly Anna Syndrome*

The “Polly Anna Syndrome,” in which the focus is only on the successes of the past rather than on future challenges, coupled with an unwillingness to recognize and learn from the mistakes of the past, becomes an obstacle to sweeping approaches to problem solving.

### *Industry Leadership*

Industry leaders can create obstacles in creative and innovative thinking by constantly shifting organizational priorities, having a lack of buy-in, micromanaging employees, and not offering reward and recognition programs.

## *Human Factors*

Industry left-brain leaders, who believe that analytical thinking is king, forget that the human factor in problem solving is what fosters innovative solutions. Focusing on the customer and understanding customers' needs are integral to the success of creative and innovative problem solving.

## *Inventive Thinking Training*

There are techniques to developing inventive thinking, which, when properly implemented, can lead to problem solving in industry. If organizations do not commit to investing in the development of these skill sets and in innovation coaching, change is not likely to occur.

## *Organizational Vision or Lack Thereof*

Organizations that have difficulty with creative and innovative problem solving typically lack a shared organizational vision, have heavy workforce workloads, and reward crisis management rather than crisis prevention. These organizations continue to sustain the status quo to support existing political agendas. They also have a problem stopping unsuccessful initiatives that have been funded and staffed. Obstacles also occur when organizations transfer the whole responsibility of innovation to Research and Development (Idea Champions, 2005).

## **The Need for Training and Education**

Innovation skills are intrinsically tied to the economy. The U.S. is not providing university students and industry leaders with the skills they need to innovate, according to a report by the United States National Innovation Initiative, commissioned by the Council on Competitiveness (NII, 2004). The report recommends that universities teach these skills to industry, educators, and university students. Other countries have begun the implementation of innovation skills policy, including Australia (AG, 2005), European Union (EC, 2005), and Canada (CBC, 2005). We, as Americans, are losing the competitive edge.

Payoffs of investing in new innovations are significant. Case studies of 108 new business launches demonstrated that investing in innovation results in critical payoffs (Kim & Mauborgne, 2005). Firms were found to have

payoffs of 38 percent of total revenues and 61 percent of total profits. What is missing is how to apply these identified skills on real-world problems in industry, how to create an organization that is receptive to innovative and creative problem solving, and how to teach and train individuals how to think differently.

Not since the Soviet Union sent the sputnik into space has the United States been called to action to become more competitive through creative and innovative problem solving. The National Innovation Initiative Report, which was chaired by Nick Donofrio, IBM's Senior Vice President for Technology and Manufacturing, was delivered to President Bush in December 2004 (Donofrio, 2004). The findings were founded on the collaborate work of a panel that consisted of government officials, corporate leaders, and university think tank scholars. This report came as a call to action and a warning. The message delivered was that if businesses, academia, labor, and government leaders do not take action and embrace innovation-based strategies, the United States risks losing its standing as the 21st century global economic power.

## **The IDEaLaboratory Purpose**

The IDEaLaboratory concept was initiated by Dr. La Verne Abe Harris from the Graphic Information Technology discipline in the Department of Technology Management in the College of Science and Technology. The IDEaLaboratory—an interdisciplinary, content-independent idea engineering studio at Arizona State University at the Polytechnic campus in Mesa, Arizona—was formed as a response to the call to action report from the National Innovation Initiative (NII, 2004). The IDEaLaboratory embraces creative thinking approaches to innovative design and technology-based solutions.

The IDEaLaboratory is a creative and innovative problem solving and usability engineering research lab. It is both a resource for university students in the technology-threaded Polytechnic campus at ASU and a resource for industry leaders and educators. The ASU Polytechnic campus mission includes integrating practical and theoretical study and engaging in research that emphasizes problem solving, ethics, and knowledge that is applied (ASU [http://www.east.asu.edu/about/provost/presentations/polytechnic\\_core.html](http://www.east.asu.edu/about/provost/presentations/polytechnic_core.html), 2005).

## Research, Development, and Entrepreneurial Agendas

As an academic unit, the IDEaLaboratory is a research and development laboratory. Five students from the IDEaLaboratory recently researched and produced a rich media project in collaboration with Northwestern University Feinberg School of Medicine. The independent study project illustrated an emerging technology—electroporation surgery for lung cancer—through multimedia with videography.

Other IDEaLaboratory research and development projects are in progress. Arizona Board of Regents (ABOR) funding is providing the opportunity for students in the IDEaLaboratory to research and develop the IDEaBook for learner-centered education, a faculty resource website with interactive tools and video clip best practices. ASU Foundation Women & Philanthropy's commitment to lifelong learning resulted in funding seed money for the IDEaLaboratory to research and produce virtual laboratories—movie clips of laboratory procedures to be used for online education. The funding includes the purchase of video hardware and software. Hewlett Packard is funding the design, printing, and dissemination of "Whispered Words," an American Indian storytelling digital publication, in addition to \$58,000 worth of HP equipment.

As an example of academic capitalism, the IDEaLaboratory is also an entrepreneurial unit (Slaughter, 1998). In addition to academic research and development, the IDEaLaboratory acts as an information design agency for print and multimedia. Entrepreneurial IDEaLaboratory activities include the development of branding, identity marks, and other marketing collateral.

The IDEaLaboratory is an integral part of a larger university infrastructure—the Arizona State University's newly-formed Advanced Technology Innovation Collaboratory (ATIC) Federation. The ATIC is an infrastructure that enables innovation through product development partnerships between ASU and small and medium-sized enterprises. Potential future business collaborations include three pilot projects: (1) agile software development methods leveraging open source software; (2) improvements in the economy of energy conversion systems through fuel economy technology; and (3) global product design.

## Curriculum Design

The inspiration for the curriculum of the IDEaLaboratory is based on an undergraduate course at Florida Atlantic University, "Introduction to Inventive Problem Solving in Engineering." The course is based on the application of an innovation tool, "Eight Dimensional Methodology for Innovative Thinking," designed by Daniel Raviv, an engineer from the Robotics Center and Department of Electrical Engineering at the University. This innovation tool was made possible through the funding of a National Science Foundation grant based on results of the NSF's grant #IIS-9615688 (Robotics and Intelligent Systems) on inventive thinking. The NSF grant strategies are uniqueness, dimensionality, directionality, consolidation, segmentation, modification, similarity, and experimentation. These strategies are geared toward those undergraduates in science, math, engineering, and technology (Raviv, 1999).

Edward de Bono, one of the internationally well-known experts in creativity, promotes creativity as a skill through lateral thinking and the Six Thinking Hats process for use in the workplace (deBono, 1971, 1985, 1990, 1990, 1992, 1994, 1995, 2005). Wearing one hat at a time when considering solutions to a problem allows the problem to be approached through six different perspectives. Strategies, such as de Bono's are incorporated into the course, along with Mind Mapping (Buzon, 1983; Wycoff 1991), Metaphoric Thinking and SCAMPER (Osborn, 1979). A technical innovation strategy called SIT (Systematic Inventive Thinking) is derived from TRIZ (the Russian acronym for Theory of Inventive Problem Solving) (Kaplan, 1997; Terniko et al., 1997). TRIZ examines how to define a problem and generate fresh, new ideas.

The first phase of the IDEaLaboratory curriculum is to design a course with similarities to the successful "Eight Dimensional Methodology for Innovative Thinking" course. It will present various strategies for creative thinking and problem-based learning and will include innovative and creative activities that augment problem-solving strategies, such as games, design projects, mind teasers, and puzzles (Anderson, 2002; Kordemsky, 1992; Rohrer, 1993, 1994; Townsend, 1988, 1993).

The IDEaLaboratory's initial curriculum will be different than Raviv's course in several ways. The interdisciplinary nature of the IDEaLaboratory creates opportunities to partner with other academic units, so it will be based on the



constructivist theory that builds on extensive problem solving knowledge from different disciplines. It will be focused on the development of cross-disciplinary thinking skills, encompassing students in business, education, humanities and arts, and media studies, as well as those in science, math, engineering, and technology. It will be a general education upper-division course open to all students.

A second course will be an interdisciplinary capstone course focusing on real world design and technological solutions. Students will be working to solve industry problems with ethical and societal considerations. Industry mentors will be an integral part of this course. In addition to presenting products, processes, or services solutions to industry leaders, students will plan a branding and marketing strategy for the project and present their solutions to an industrial partner. Undergraduate ASU seniors working on their capstone project, and ASU graduate students working on their applied project or thesis, will comprise the proposed think tank pods. Each pod will consist of four university seniors or graduate students from diverse disciplinary backgrounds. The IDeaLaboratory will be the hub to develop research, applied projects, and a capstone experience in cross-platformed communications on the Polytechnic campus. For example, the solution to the industry problem may end up as a software program in the I3DEA computer studies laboratory, as a prototype in the Engineering Studio, or as a variable data publication in the Graphic Information Solutions print facility.

## Partnerships

The IDeaLaboratory has partnered with several industry leaders in the community. The Joint Alliance of Companies Managing Education for Technology (JACMET) is a partner of the IDeaLaboratory. Members from companies such as Intel, Motorola, Honeywell, and Boeing work cooperatively with ASU, University of Arizona, and Northern Arizona University. This organization has grown out of a government National Science Foundation Project (TRP Technology Reinvestment Project #3518), which was initiated in 1994 in Arizona (JACMET, 2005).

Google.com recently announced that it will open up another “google mothership” in Phoenix (Harris, 2005). They are partnering with ASU and will be a resource for the IDeaLaboratory.

The Advanced Reality Training Institute (ARTI), a non-profit organization, is another partner of the IDeaLaboratory. This organization focuses on enhancing response skills for low frequency, high-risk events in terrorism, crime, and disasters. Marsha Petrie Sue, professional speaker, author, and former Executive Vice President of Westinghouse Financial American Directory Project, is another partner of IDeaLaboratory.

Because the IDeaLaboratory is a part of ASU’s Advanced Technology Innovation Center (ATIC) Federation, it has many university laboratory partners and academic units as resources. The Graphic Information Solutions print facility, the Digital Photography Laboratory, and the Student Web Development Enterprise (SWDE) are technology management partners with the IDeaLaboratory, along with the Engineering Studio on the Polytechnic campus, the I3DEA (Computer Studies Lab), and the InnovationSpace on the Tempe campus, among others.

Developing high-quality ideas to serve as alternative solutions to problems in today’s workplace requires inventive thinking. In the Polytechnic core courses at ASU, this type of thinking requires that ethical issues to be a significant part of the decision-making process. The problem-based learning will be both systematic and nonsystematic, so that students will learn to solve problems in an inventive manner. The IDeaLaboratory course will be founded on strategies that have been used successfully in business and industry.

## Future Directions

ASU’s IDeaLaboratory embraces research and development, entrepreneurial activities, and curriculum design agendas. Since the curriculum design and the small to medium-sized business networking are in the planning stages, I will continue to report on the evolving research and development, entrepreneurial activities, and course curriculum progress to enhance the thinking skills of the Polytechnic students. To help focus the IDeaLaboratory’s future direction, a needs assessment survey from industry was completed in January 2006. Based on the results of the survey, IDeaLaboratory activities will be designed around the priorities and needs that industrial professionals believe are lacking in today’s employees in the business and industrial world. Continued interaction with industry leaders will form a basis of the IDeaLaboratory’s future endeavors.

Because of the mission of Arizona State University Polytechnic campus, the shifting pedagogy of traditional lecture-only environment to that of a learner-centered and problem-based learning environment, the needs of the student, educator, and industry leader will be met in the IDEaLaboratory. By incorporating the creative and innovative approach to problem solving through the IDEaLaboratory, classroom projects and continuing education units can be transformed into transferable learning. The use of technology to solve real-world problems in a creative and innovative manner through a university-led laboratory is a response to the Government's call to action. Through this embedded relationship between the public university, industry, and education, ASU can make a contribution to the National Innovative Initiative, to the economy of the United States, and to society as a whole.

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***This is a juried article***

# A Study of Color Printing Attributes of Inkjet Printers for Artwork Reproduction

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## Introduction

In the digital era, countries all over the world devote time to digitizing their cultural treasures and heritage. By means of digitalization, humans can preserve while still utilizing their cultural heritage. In the process of digitalization, substrates play a vital role in obtaining a desired color reproduction. Two-dimensional artworks reproduced by the digital archive industry, such as oil paintings, watercolors, and calligraphy, need suitable substrates to present their correct and detailed color. This is especially true if the original artwork will be archived for preservation and the reproduction used in its place.

Based on the need for 2D artwork reproduction and preservation, Sheng Hung Industrial Co., LTD in Taipei, Taiwan, invented a new substrate, P-TEX Cloth, for color ink-jet and lithographic printing. It was observed that the printing quality on P-TEX Cloth was generally better than that on paper, especially for oil paintings, watercolors, and calligraphy. Thus, there is a great need to investigate how to apply a color management system (CMS) to control and then improve digital color reproduction quality on the P-TEX Cloth substrate.

## Statement of the Problem

P-TEX Cloth consists of non-woven material combined with nanotechnology to become a type of environmentally friendly printing substrate. It has the advantages of showing fine detail, is non-reflective, is difficult to tear, is crease-free, has a precise cutting edge, and is easy to store. With these advantages, P-TEX Cloth is an excellent substrate choice for duplicating artwork. It is, however, a new substrate for 2D artwork duplication. Therefore, controlling and improving digital color reproduction quality on P-TEX Cloth through color management techniques is a new challenge for printers.

## Needs and Purposes for the Study

Substrates are definitely dominant variables in predicting and reproducing color. Using advanced color management system (CMS) applications, printers can

ensure process consistency of color reproduction via output device calibration and the construction of ICC profiles for particular processes. Through the use of suitable ICC profiles, P-TEX Cloth can be an excellent choice for 2D artwork duplication when it is used as the substrate.

The main purposes of this study were: 1) to construct the most optimum ICC profile for P-TEX Cloth, 2) to analyze the substrate's color printing attributes when the optimum profile is used to output reproductions; and 3) to determine if a custom ICC printer does a better job in color image reproduction than generic ICC profiles. The term "optimum ICC profile" in this study refers to a profile that allows a printer to linearize (optimize) the color image reproduction process with the optimum amount of ink coverage. Linearization is usually called LAB linearization and it is the extension of the calibration concept in color management (Sharma, 2004). The output devices used in this study were an Epson Stylus Pro 9600 printer with pigment inks and a HP 5500 printer with dye ink.

Once the print attribute specification for P-TEX Cloth is established, it can be used as a reference for the digital printing industry, and also be applied to the digital archive industry for output substrates.

## Methodology

This study was designed to construct the optimum ICC profile for P-TEX Cloth and analyze the substrate's color printing attributes when the optimum ICC profile is used to output reproductions of original artwork. Functionally, there are two kinds of software to control a printer in terms of output quality: the printer driver (inkjet printer manufacturer's software) and the third-party raster imaging processor (RIP) software. Print driver software drives the printer to print data files in the RGB model. A user sends an RGB image and the printer driver performs the conversion from RGB to CMYK. The RGB printer requires the use of an RGB test chart, such as TC9.18 or TC2.83, to create an ICC profile. Conversely, a RIP's software interprets raster and vector data files for a specific PostScript printer using a CMYK model. If a user chooses RIP software that directly con-

trols CMYK inks, the output device should be treated as a CMYK device. Therefore, a CMYK test chart, such as IT 8.7/3 or ECI 2002, must be used to create an ICC profile.

The application of an RGB or CMYK device will depend on the user's workflow. In this study, both RGB and CMYK output models were investigated. The RGB output model utilized by the study was the Epson Stylus Pro 9600's print driver. Best Colorproof RIP (now EFI) was employed as the CMYK model. The profile-making software used was Gretag Macth ProfileMaker and the output devices were the Epson Stylus Pro 9600 printer with pigment ink and the HP 5500 printer with dye ink.

### The Test Form

A digital four-color test form was designed for this study. The test form is 8.27" × 11.69" in size, and includes test targets and photographic images (as shown in Figure 1). The photographs in the test form are GATF complex CMYK images that emphasize different color reproduction challenges. The other process characterization targets of the test form include an ink coverage target; CMYKRGB and 3K solid patches; tone scales of CMYKOG, CMYKRGB and 4K tint patches (5%~100%, in a 5% interval); and a micro line target.

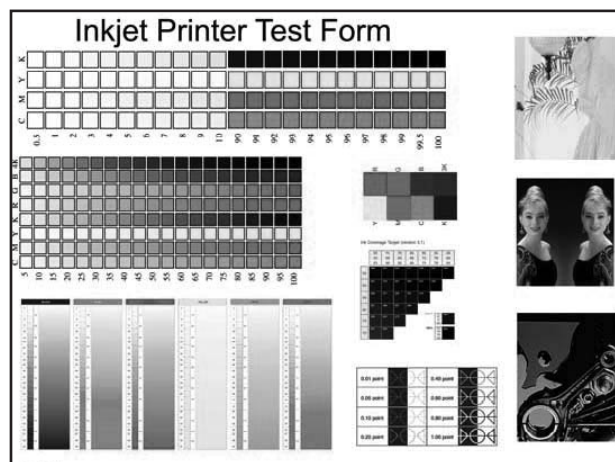


Figure 1. Digital Test Form

### Research Procedure

Due to time and budget constraints, the output models combined with ICC profiles used in this study were limited to three combinations: 1) Epson 9600 printer with its

own printer driver; 2) Epson 9600 printer with the Best Colorproof RIP output model; and 3) HP5500 printer with the Best Colorproof RIP output model.

### RGB Output Model

The procedure used with the RGB model is much simpler than CMYK model. The printer driver cannot limit the amount of CMYK ink. When using an RGB device and creating an ICC profile for P-Tex Cloth, the steps are as follows:

1. Open Adobe Photoshop.
2. Open the TC 9.18 test chart and print it without using color management.
3. Measure the TC 9.18 test chart, collect the CIELAB values of each patch in the chart, and create an ICC profile using ProfileMaker software.
4. Open the "digital test form" created for this study in Adobe Photoshop. Then, convert the digital test form using the ICC profile generated from ProfileMaker software for the Epson 9600 printer.
5. In order to conduct statistical analysis, 35 P-Tex Cloth substrates were printed.

### CMYK Output Model

Most high-end inkjet printers are designed to be used with a third-party raster imaging processor (RIP) to control color-proofing. That is, the RIP is used to control CMYK inks directly and incorporate color management during the output process. When using RIP software to control an inkjet printer, the first step is device calibration. The goal of calibration is to bring the printer into a stable and standard condition and to achieve predictable behavior. The calibration process consists of ink limitation and linearization. Ink limitation adjusts the amount of all inks distributed on the media and thus optimizes image tone reproduction.

Global ink limitation, which governs the amount of all inks together, is best controlled during the profile-making step. While the maximum amount of ink is fixed by the ink limitations, setting the tonal behavior can be adjusted by linearization. Linearization is a technique for creating repeatable and predictable printer behavior. A

linearization test target incorporates a set of color patches for each color that a printer would output, such as cyan, magenta, yellow, and black. The linearization test target patches are arranged in steps that range from light to dark. RIP software automatically adjusts the steps on the linearization target.

Calibration is a vital step in color management. Once the ink limitation and linearization are fixed, the color performance of the device would be determined at the same time; that is, the ICC profile would be affected by the result of calibration.

The second step in color management system is characterization. In order to complete a color-managed system to achieve the most accurate color matching, the printer needs custom ICC profiles for the input, display, and output devices. To determine which of the correct linearization settings is optimum for the RIP, it is necessary to experiment with different linearization settings and profile combinations to see how more or less inkjet printing would affect the final prints.

The steps to use a CMYK device and create an ICC profile for P-TEX Cloth in this experiment are as follows:

1. Open Best Colorproof RIP software.
2. Create a folder for P-TEX Cloth and set up output conditions in the Best Colorproof RIP, such as type of ink, resolution, and so on.
3. Calibration
  - set up and determine ink limitation
  - print out linearization test target and measure each patch of all colors on the target
  - create a linearization file for P-TEX Clothes
  - conduct a series of trial-and-error tests to find the optimum linearization
4. Characterization
  - use the optimum linearization to output the European Color Initiative (ECI) 2002 Target
  - measure ECI 2002 target, collect all CIELAB values of each patch in the chart and create an ICC profile using ProfileMaker software.
5. Set up the color management functions in Best Colorproof RIP, such as type of ink, resolution, type of paper, linearization files, ICC profiles, CMYK render-

Output Model		Epson 9600 with printer driver	Epson 9600 with Best Colorproof RIP				HP5500 with Best Colorproof RIP			
Type of Ink		Pigment	Pigment				Dye			
Resolution		1440×720 dpi	1440×720 dpi				1200×600 dpi			
Calibration	Ink Limitation (TAC)	N/A	220				120			
	Linearization Test Target	N/A	Baselin_SpectroScan				Baselin_SpectroScan			
	Measure Tool	N/A	SpectroScan				SpectroScan			
	Linearization - solid ink density for YMCK color	None	Y	M	C	K	Y	M	C	K
		1.28	1.20	1.07	1.30	1.21	1.46	1.06	1.67	
Characterization	Test Target	TC 918 target	ECI 2002 target				ECI 2002 target			
	Measure Tool	SpectroScan	SpectroScan				SpectroScan			
	Profile Making Software	GretagMacbeth's ProfileMaker	GretagMacbeth's ProfileMaker				GretagMacbeth's ProfileMaker			
P-TEX Clothes Output	Test target	Digital Test Form (assign RGB ICC profile to output)	Digital Test Form (assign CMYK ICC profile to output)				Digital Test Form (assign CMYK ICC profile to output)			
	Number of sheets output	35	35				35			

Table 1. The output conditions and equipment of the experiment

ing intents, RGB rendering intents, CIELAB rendering intents, and so on.

6. Open the “digital test form” of this study in Adobe Photoshop. The ICC profile for P-*Tex* Cloth is converted with the data file.
7. Open the “digital test form” converted with the CMYK ICC profile in the Best Colorproof RIP software. The test form is printed through the Best Colorproof RIP. The printer profile created by ECI 2002 is then applied during the process of printing. Thirty-five P-*Tex* Cloth substrates are printed for further statistical analysis.

The details of output conditions and equipment of the experiment for RGB and CMYK output model are presented in Table 1.

### Data Collection

Thirty-five printed P-*Tex* Cloth samples were collected from each of the three output combinations (as shown in Table 1). Therefore, a total of 105 P-*Tex* Cloth were sampled. An X-Rite 530 spectrodensitometer, using the Murray-Davies equation ( $n = 1$ ) with status “T” filter, was used to measure samples of solid ink density, tone value increase (10%, 25%, 50%, 75%, 90%), print contrast (75%), hue error and grayness, and CIELAB values. The SPSS 12.0 statistical software package was used for data analyses. It is important to note that each specific patch on the sampled sheets was measured only one time due to time constraints.

## Results and Findings

The overall results of color reproduction for samples of P-*Tex* Cloth are displayed from Table 2 to Table 5. The solid ink density, 10%–90% tone value increase, and print contrast are listed and categorized according to the three print output models as shown in Table 1. Furthermore, the study mea-

sured CIELAB values to construct the color gamut for the three print output models. This study also compared the differences in hue error and grayness between pigment ink (Epson 9600) and dye ink (HP5500) systems.

### Solid Ink Density

Solid ink density usually refers to the ability of a print to absorb light. In color-proofing workflows, the setup of solid ink density is a vital factor to achieve an optimum print. Once the right amount of solid ink density was decided, the RIP software automatically adjusted the steps on the linearization target; that is, it enabled a printer to deliver ink on media so an image’s tones print optimally. As shown in Table 2, the solid ink density of HP 5500 in combination with the Best Colorproof RIP output model was greater than that of the other two models. In contrast, the solid ink density of the Epson 9600 with printer driver was smaller (except for black). It is important to note that the Standard Deviation (S.D.) values of the solid ink density reading for the HP 5500 with the Best Colorproof RIP print output model were greater than those of the other two systems in all four ink colors. This means that the HP-5500 with the Best Colorproof RIP print output model had a greater ink density variability than the other two models did.

### Tone Value Increase

Table 3 depicts the 10–90% tone value increase (TVI) statistics for the three print output models. As shown in Table 3, the Epson 9600 using the Best Colorproof RIP output model printed the least TVI at 10–75 percent tone levels for all four process colors, excluding the yellow TVI at the 10% tint. For the 10–25 percent tints, the greatest TVI occurred when the HP 5500 with the Best Colorproof RIP output model was employed in all four ink colors, except for the magenta at the 25% tint. The Epson 9600 with the printer driver output model, on the other hand, printed a greater

Solid Ink Density (SID)	Epson 9600 with printer driver		Epson 9600 with Best Colorproof RIP		HP5500 with Best Colorproof RIP	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Y	0.74	.00507	0.75	.00514	0.79	.00530
M	0.88	.00676	0.99	.00657	1.17	.00891
C	0.65	.00471	0.94	.00664	1.13	.01937
K	1.15	.00874	1.04	.00558	1.20	.01172

Table 2. Descriptive statistics of solid ink density for the three print output models



TVI than the other models did, especially between 50–90% tints (with the exception of the cyan TVI at 75% and 90% tints). As for the dot reproduction stability, as shown in the Standard Deviation (S.D.) columns of Table 3, the Epson 9600 using the printer driver output model printed greater dot reproduction variability than the other models did at 10%, 25%, and 90% tints.

The TVI curves of the 10%-90% tints are exhibited in Figure 2. The greatest TVI occurred at 50% tints for the three output models. Among the three output models, Figure 2 shows that the Epson 9600 with the Best Colorproof RIP output model (dashed line) printed the least TVI and Epson 9600 with the printer driver (thin line) yielded the greatest

TVI among the 50-90% tints. It is also important to note that the TVI values between the 10%-25% tints for the HP 5500 with Best Colorproof RIP model were greater than the other two systems in yellow, cyan, and black.

### Print Contrast

Print contrast (PC) is a quality index that is calculated using the solid and 75% tint patches. The value is a measure of shadow contrast and is the degree to which viewers can distinguish printed tones in the shadow area of a reproduction. In general, the higher the print contrast the better the shadow detail rendition. Table 4 displays the average print contrast percentages for the three print out-

Tone Value Increase (TVI)		Epson 9600 with printer driver		Epson 9600 with Best Colorproof RIP		HP5500 with Best Colorproof RIP	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
10% TVI	Y	10.63	1.14	13.74	0.70	21.00	0.91
	M	12.86	0.81	12.51	0.56	16.66	0.54
	C	14.66	1.11	10.40	0.81	15.51	0.74
	K	10.26	0.82	9.51	0.70	14.51	2.63
25% TVI	Y	23.97	0.95	17.74	0.82	30.37	0.77
	M	30.03	0.66	17.49	0.66	22.94	0.59
	C	26.80	0.90	17.37	0.55	27.17	0.62
	K	20.46	0.74	14.60	0.50	21.11	0.53
50% TVI	Y	31.20	0.41	19.09	0.74	28.97	0.51
	M	34.00	0.24	23.54	0.51	25.06	0.24
	C	39.14	0.36	22.34	0.48	29.80	0.58
	K	29.11	0.99	19.00	0.24	23.09	0.37
75% TVI	Y	20.97	0.17	12.77	0.49	15.91	0.37
	M	21.91	0.28	16.03	0.17	16.71	0.52
	C	17.69	0.47	17.49	0.66	22.40	0.50
	K	21.00	0.00	12.00	0.00	14.74	0.44
90% TVI	Y	9.00	0.00	7.00	0.24	8.00	0.00
	M	9.00	0.00	8.20	0.41	8.00	0.00
	C	7.03	0.17	8.77	0.43	10.0	0.28
	K	10.00	0.00	5.97	0.17	6.80	0.41

Table 3. Descriptive statistics of tone value increase for the three print output models

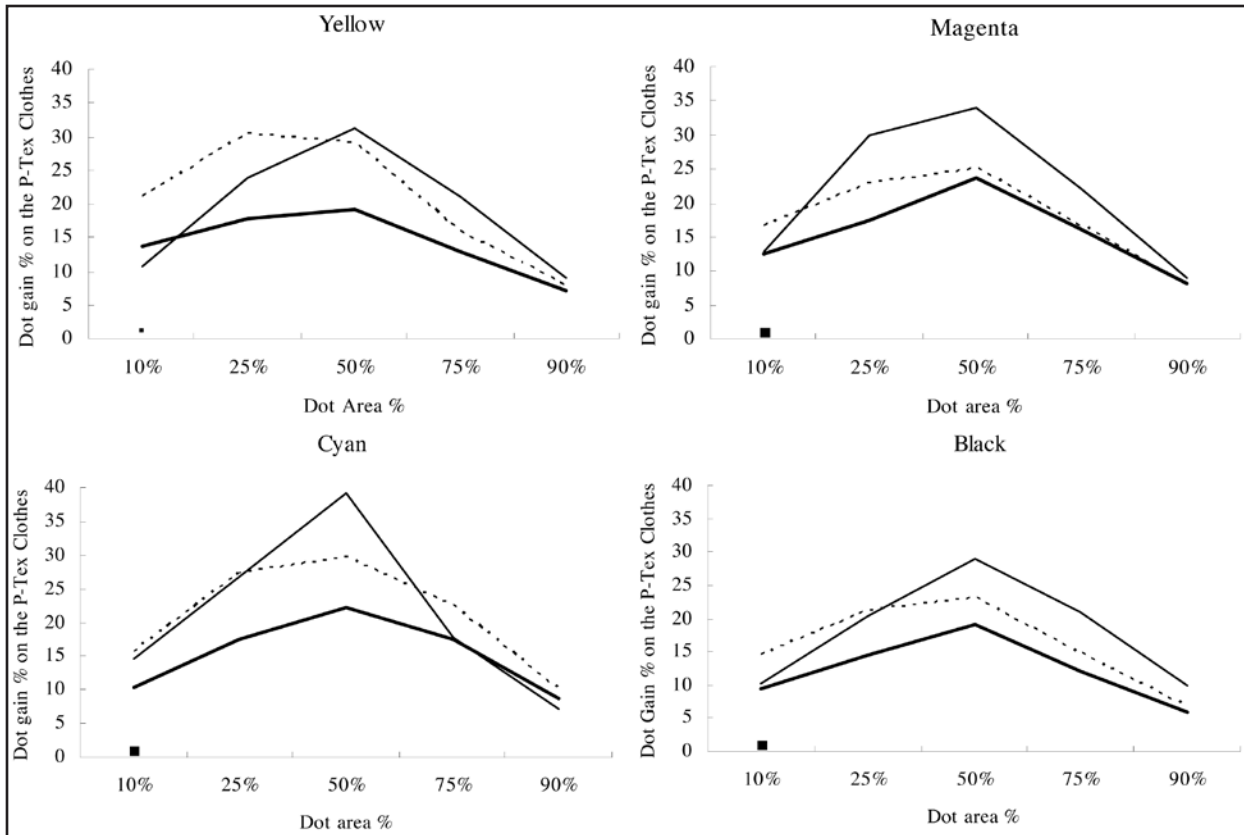


Figure 2. 10%~90% TVI curve

Note: Thin line represents Epson 9600 with printer driver output model  
 Thick line represents Epson 9600 with Best Colorproof RIP output model  
 Dashed line represents HP 5500 with Best Colorproof RIP output model

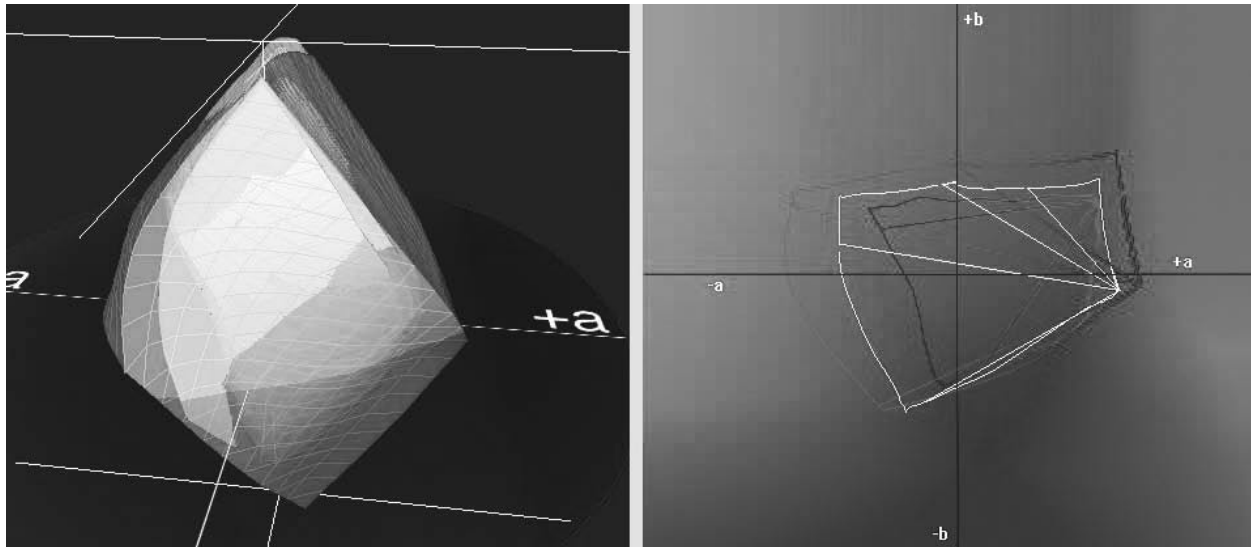
Print Contrast (PC)	Epson 9600 with printer driver		Epson 9600 with Best Colorproof RIP		HP5500 with Best Colorproof RIP	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Y	9.80	0.53	27.46	0.70	21.14	0.49
M	9.51	0.78	25.80	0.41	29.60	0.78
C	15.11	0.76	22.11	0.58	10.94	1.35
K	16.69	0.63	39.20	0.72	40.20	0.68

Table 4. Descriptive statistics of print contrast for the three print output models

put models. The results indicate that the Epson 9600 with the Best Colorproof RIP output model had the greatest print contrast percentage values for yellow and cyan; the HP 5500, with the Best Colorproof RIP output model, on the other hand, had the greatest print contrast percentage values for magenta and black. It is important to note that the maximum print contrast value was found in black for all three models.

### Color Gamut

The color gamut of the three output models were illustrated from the most optimum ICC profile for P-TEX Cloth. Figure 3 is the result of using Monaco Profiler's Gamut Work to plot 3D and 2D diagrams of CIELAB color. The blue, yellow, and red color represents the HP 5500 with Best Colorproof RIP, Epson 9600 with the Best Colorproof



**Figure 3. The color gamut for the three print output models**  
 Note: Blue color represents HP 5500 with Best Colorproof RIP output model  
 Yellow color represents Epson 9600 with Best Colorproof RIP output model.  
 Red color represents Epson 9600 with printer driver output model.

RIP, and Epson 9600 with the printer driver, respectively. As shown in Figure 3, the HP 5500 with the Best Colorproof RIP (blue color) printed a wider color gamut (Gamut Volume = 868,564) than the others did, and the Epson 9600 with the printer driver (red color) printed the smallest color gamut among the three (Gamut Volume = 453,028).

### Hue Error and Grayness

Both hue error and grayness measurements are concerned with the color purity of an ink. Hue means the name of a color (i.e., magenta, yellow, red, and so on) and error applies to the deviation from the ideal color. Hue error refers to the amount of contamination (or color shift) that a particular pigment displays. The more hue error a pigment possesses, the more difficult it becomes to accurately reproduce certain colors. If a process color is contam-

inated by the other two colors, the result is gray. This is referred to as grayness; grayed inks are also commonly called “muddy.” The degree of grayness limits the ability of the pigment to reproduce clean secondary colors (Coudray, 1990).

Color shift typically happens in color and neutral shadow areas of a print. This problem is related to impurities in the inkjet inks. In the digital proofing process, there is always the debate over whether dyes or pigments are better for proofing. Dye ink provides bright colors with a broad gamut (as shown in Figure 3). However, pigmented inkjet ink is the best match to real pigmented offset inks, and pigments are very stable over a long period of time. As for the color purity of pigment or dye ink, the overall results of the hue error and grayness are displayed in Table 5. Both hue error and grayness values of the pigment ink were lower than those of the dye ink in all of the cyan, magenta, and

Color	Pigment Ink (Epson 9600 Printer)		Dye Ink (HP 5500 Printer)	
	Hue Error %	Grayness %	Hue Error %	Grayness %
Y hue error to M	12.97	2.97	13.89	6.94
M hue error to Y	53.51	22.66	50.03	16.63
C hue error to M	17.83	17.83	21.06	13.51

Table 5. Statistics of hue error and grayness values

yellow inks except for the hue error and grayness of magenta and grayness of cyan.

## Conclusions and Recommendations

The following limitations are important while interpreting the conclusions of this study:

1. Each specific patch on the printed substrates was read only one time due to the constraints.
2. Two different inkjet output systems (Epson Stylus Pro 9600 and HP DesignJet 5500) were used for this research. Their designs, components, ages, and other physical and chemical conditions differed. Their effects on the results of this study were not further explored.
3. All tint values on the printed paper were measured by the Murray-Davies equation and the measuring procedures were determined based on the recommendations of the densitometer manufacturer.
4. This research was to study if a custom ICC profile does a better job in color image reproduction than generic ICC profiles based on a cloth substrate; the material and production costs for the output were not studied. However, the main interest of the study was to analyze the color reproduction performance for P-Tex Cloth when the optimum ICC profile was used to convert an original image for reproduction.

This experimental study constructed the most optimum ICC profile for P-Tex Cloth. Furthermore, this study analyzed color reproduction performance when the optimum profile was used during the reproduction of originals. The overall conclusions are listed below:

1. The HP 5500 with the Best Colorproof RIP output model printed greater solid ink density and density variability than the other two models. In contrast, the solid ink density of Epson 9600 with the printer driver was smaller than that of the other two models.
2. Regarding dot reproduction, the greatest TVI occurred at 50% tints for all the three output models. The Epson 9600 with the Best Colorproof RIP printed the least TVI between 10–90% tints, and the Epson 9600 with the printer driver yielded the great-

est TVI between 50–90% tints among the three models. It is also important to note that the TVI values between 10%–25% tints of the HP 5500 with the Best Colorproof RIP output model were greater than those of the other two systems in yellow, cyan, and black.

3. The Epson 9600 with the Best Colorproof RIP output model had the greatest print contrast percentage values in yellow and cyan while the HP 5500 with the Best Colorproof RIP model printed better contrast in magenta and black.
4. The HP 5500 with the Best Colorproof RIP printed a wider color gamut than the others while the Epson 9600 with the printer driver yielded the smallest color gamut among the three.
5. In this study, the Epson proofer used pigment ink and the HP proofer printed with dye ink. This study shows that both hue error and grayness values of the substrates printed using Epson's pigment ink were lower than those printed using HP's dye ink in cyan, magenta, and yellow.
6. The output model of HP 5500 with the Best Colorproof RIP using dye ink did provide bright colors with a broad gamut, especially in shadows, for P-Tex Cloth. However, the study found that the color of dye ink started to fade away in about two weeks and it tended to exhibit color shifts during the experiment. This study suggests that P-Tex Cloth printed via the HP 5500 with Best Colorproof RIP could be applied when printing exhibition posters or similar products which do not require high quality color longevity.
7. The Epson 9600 with the Best Colorproof RIP output model printed smaller TVI between 10–90% tints than the other models. In other words, it provided good tonal gradation. Furthermore, the study found that the color printed using the Epson 9600 with the Best Colorproof RIP on P-Tex Cloth is relatively stable over a long period of time although its color is not as bright as that of the HP 5500 with the Best Colorproof RIP. It is suggested that P-Tex Cloth printed using the Epson printer with Best Colorproof RIP could be applied in artwork duplication for the purpose of reproducing cultural treasures and for heritage preservation.

8. The study found that a proofer in combination with an optimum RIP does a better job of directly controlling CMYK inks for obtaining desired color than a proofer without a RIP. The tone value increase and print contrast performance of a proofer with proper RIP settings are better than those without RIPs. It is important to note that without ink limit control function, the RGB output model printed greater TVI and smaller print contrast on P-TEX Cloth.

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*This is a refereed article*

## Appendix

Summary of color characteristics for P-TEX Cloth

		Epson 9600 with printer driver	Epson 9600 with Best Colorproof RIP	HP5500 with Best Colorproof RIP
Solid Ink Density (SID)	Y	0.74	0.75	0.79
	M	0.88	0.99	1.17
	C	0.65	0.94	1.13
	K	1.15	1.04	1.20
10% Tone Value Increase (TVI)	Y	10.63	13.74	21.00
	M	12.86	12.51	16.66
	C	14.66	10.40	15.51
	K	10.26	9.51	14.51
25% Tone Value Increase (TVI)	Y	23.97	17.74	30.37
	M	30.03	17.49	22.94
	C	26.80	17.37	27.17
	K	20.46	14.60	21.11
50% Tone Value Increase (TVI)	Y	31.20	19.09	28.97
	M	34.00	23.54	25.06
	C	39.14	22.34	29.80
	K	29.11	19.00	23.09
75% Tone Value Increase (TVI)	Y	20.97	12.77	15.91
	M	21.91	16.03	16.71
	C	17.69	17.49	22.40
	K	21.00	12.00	14.74
90% Tone Value Increase (TVI)	Y	9.00	7.00	8.00
	M	9.00	8.20	8.00
	C	7.03	8.77	10.0
	K	10.00	5.97	6.80
Print Contrast (PC)	Y	9.80	27.46	21.14
	M	9.51	25.80	29.60
	C	15.11	22.11	10.94
	K	16.69	39.20	40.20



# Avoiding Moiré in Screen Printing

by David W. Dailey, Ed.D., Eastern Kentucky University

## Background and Statement of the Problem

Screen printing is a means of printing in which ink is forced through a stencil in a screen onto paper, glass, textiles, or numerous other surfaces. The process began over a thousand years ago when the Chinese and Japanese began experimenting with a stencil process that has become known today as screen printing.

If one were going to create a stencil for the letter “T,” it would be a simple process to cut out and remove the letter. But if an “O” were to be cut out, the center of the letter would come out and just a spot would be printed rather than the letter. The center is what is known as an island area. The Orientals developed a technique to hold the elements (island areas) of a stencil together with strands of human hair. The printing process saw further improvements in Europe as the stencil was placed over a piece of tightly stretched silk. Further improvements saw the development of hand-cut stencil films and, most recently, liquid emulsion stencil materials. The use of silk, and the name many use for the process, “silkscreen printing,” has been replaced with polyester fabrics and the process is simply called screen printing.

Many jobs that are screen printed call for solid areas of color or type, and this does not present a significant problem for the printer. But customers often require the use of photographs as a part of the job requirements. Printing a photograph is a different matter altogether than printing solid colors, because photos require shades of gray rather than just black or white or solid color. This requires the printer to produce what is called a halftone, creating an illusion of the original continuous tone photograph.

A concern to printers in the reproduction of photographs is the appearance of the dreaded moiré pattern. Prust (2003) states that this “pattern is a visually undesirable dot-exaggerating effect that occurs when two different screen patterns are randomly positioned or superimposed” (p. 280). For printers employing the offset lithographic process, the effect most often occurred when producing duotones or process color by traditional screening methods. Prior to the adoption of computer technology, black and white photographs were reproduced using camera contact screens with a built-in dot angle

of 45°. This angle is more pleasing to view since the human eye can best differentiate verticals and horizontals.

When a job called for a duotone or process color, screen angles became a concern. Duotones require two halftones which must have dot angles 30° apart to avoid the moiré pattern. Anything even slightly more or less showed up as a moiré pattern when the job was proofed or printed. Due to the anomalies of film, the pattern did not show when viewing film negatives or the problem was imperceptible.

This 30° difference also had to occur when printing process color. The major problem with the 30° angle difference is that only three angles and, therefore, only three colors, will fit around a 360° circle. Black was usually printed at 45°, cyan at 105°, and magenta at 75°. This left yellow at 90°, thus violating the 30° angle difference rule, and the moiré pattern was evident. But since yellow is such a light color, the moiré is not as noticeable or objectionable (Prust, 2003).

As printers moved from camera-produced halftones and separations to imagesetter production, the angles changed as programmed by the imagesetter manufacturer. Reliance on a skilled craftsman in the darkroom became a thing of the past. Screens no longer had to be manipulated manually to achieve the 30° angle change and avoid the moiré. Jobs are produced on the computer using current photo editing and page layout software and films are output through the imagesetter correctly angled. Current technology allows the printer to move a job from the computer, direct-to-plate, or direct-to-print.

Recently, some printers have moved a step further in avoiding the moiré pattern by updating their software to produce stochastic screening. Traditional screens and imagesetters produce dots by varying the size of the dot, while spacing the dots equidistant apart. The stochastic method produces equal size dots with variable distances between them. The process is referred to as frequency modulation (FM) as opposed to amplitude modulation (AM), the more traditional method of halftone screening. In FM screening, instead of traditional halftone dots, the illusion of tones is created by spots that are placed “as a result of a complex algorithm that evaluates and distributes spots under a fixed set of parameters” (Prust, 2003, p. 245).

In light of the discussion of screen angles and lines per inch, the problem for the screen printer is aggravated by a screen mesh woven with vertical and horizontal filaments and the size of the mesh opening. The offset printer is only concerned with the image on the printing plate and its transference to the substrate, usually paper. The screen printer must be aware of screen angles to avoid moiré with the fabric weave and the size of the dots so they will not fall through the mesh.

Offset printers will often print halftones and separations at screen line rulings of 150 lines per inch (LPI) and higher, which is completely appropriate for the characteristics of the process. Some screen printers, with highly controlled processes and automated equipment, regularly print 85 to 110 LPI halftones.

However, most educational programs lack automated equipment, so student printers manually pull a squeegee over a paper or textile substrate. To ensure student success on screened projects, instructors need to consider the variables involved in moiré with the screen mesh and selection of the proper halftone dot ruling.

## Mesh Count Determination

Coudray (2002), Dolin and Adams (2002), and Gardino (2003) offer suggestions for determining suitable mesh counts and screen angles. Dolin and Adams (2003) recommend that dot sizes should range from 10 to 15 percent in the highlights to 85 to 90 percent in the shadows. Dots outside of this range will probably not reproduce. They also recommend monofilament fabrics, halftone inks, sharp squeegees, and off-contact printing.

Dolin and Adams (2002) refer to Ulano Company recommendations of “multiplying the halftone ruling by 3.5 to 4.0 to obtain a usable screen mesh range” (p. 323). In the example they provide using a 60 LPI halftone and Ulano’s multiplier, a screen mesh count of between 210 and 240 threads per inch would be required ( $60 \times 3.5 = 210$ ,  $60 \times 4.0 = 240$ ). This mesh should be considered too fine for use with poster or plastisol inks and manual squeegee operation. It is also suggested that the smallest dot requires the intersection of at least four strands of fabric for support.

Coudray (2002) also gives the 4:1 or 3.5:1 mesh to LPI ratios, but states that this range is not to be accepted as

anything more than a guide. Factors such as mesh tension affect the thread count, increasing the distance between threads as the tension increases. Halftone line count is not as accurate at either end of the tonal range as it is at 50%.

Gardino (2003) recommends a 6:1 mesh to dot ratio using the following example: 305 threads per inch require using not over a 50 LPI halftone ( $305/6 = 50$ ). He also recommends the use of elliptical dots which provide better transitions in the midtones and allow better dot adhesion to the mesh.

## Screen Angle Determination

Screen printers must also consider ways to avoid moiré when exposing screens since there is the added factor of screen mesh weave. Adams and Dolin (2002) suggest avoiding moiré by aligning the halftone with the mesh on a light table prior to exposure. In response to a question on this topic, the editor of the SGIA International Tabloid (2002) stated that a  $7^\circ - 7.5^\circ$  bias from the usual halftone angles is a good rule of thumb. Gardino (2003) indicates that “the  $7.5^\circ$  shift reduces the possibility of dot to mesh moiré. Black  $67.5^\circ$ , Cyan  $37.5^\circ$ , Magenta  $22.5^\circ$ , Yellow  $7.5^\circ$ ” (p. 16).

## What Really Works? The Test Procedure

To determine the actual best mesh count and screen angle that will not create the moiré effect, lab tests were performed. A set of ten boxes one-inch square was created in Adobe Illustrator®. Each box was filled with a dot pattern from 10 to 90%. Many screen printers have moved away from film and are outputting much of their work from a laser printer onto vellum, a translucent paper. This material requires the use of a toner aid to achieve increased density required for proper exposure. Vellum was used in this test and is suggested for educational programs without process photographic capacities.

When printing from Illustrator®, the operator has the option of setting screen angles and LPI output. Screens available in the lab for this test included 110, 160, and 195 mesh. Previous tests producing halftones using the 3.5–4 mesh to LPI ratio had given unsatisfactory results, so the 6:1 ratio suggested by Gardino (2003) was used. ( $110/6 = 18.3$  LPI,  $160/6 = 26.6$  LPI,  $195/6 = 32.5$  LPI). The screen angles he suggested were also used. Several sheets of 10–90% boxes were printed varying the LPI and the angle.



To prepare positives for exposure, sheets with various angles were cut apart and taped together providing a positive with 22.5, 37.5, and 67.5° angles. All screen emulsions were exposed from positives. The yellow angle was not included in the test. Sets of 10–90% boxes were also included that varied the screen angles. For example, the positive set for the 110 mesh screen included the three screen angle variations at 18.3 LPI as well as the 67.5 LPI set for the 160 and 195 mesh screen.

All screens were coated with a single coat of a two-part liquid emulsion on both the print and squeegee sides of the screen. Screens were dried in a horizontal position, print side down. After drying, exposure was for 55 units on an Atlas exposure unit with black lights. Screens were washed out with medium pressure cool to warm water. Each test sheet was manually printed using black poster ink, off contact with a high durometer squeegee.

## Results of the Test

With each screen, the 6:1 mesh to screen ratio suggested by Gardino (2003) provided very good results. The 7.5° angle shift on the three angles test printed without moiré. There were no apparent differences between tests printed on white or orange 110 mesh. Dots in the 10% box held best on the 110 and 160 mesh screens, with some dot loss in the 195 mesh screen. Results were not as good in the 90% box showing more dots lost to fill-in. When the 10-90% boxes were printed on the 110 and 160 mesh screens using the 32.5 LPI for the 195 screens, the moiré was very visible, which was to be expected since the LPI was wrong. Conversely, when printing with the 18 and 26.6 LPI on the 195 mesh screen, little or no moiré was visible. Results with the 195 mesh screen provided the best results in obtaining a good dot pattern across the 10 to 90% boxes.

Even though a test for the yellow printer screen angle at 7.5° was not a part of the original test, projects completed since the original testing was done have shown that this angle provides good results.

## Recommendations

From the results achieved in these tests, moiré was eliminated by following the recommendations of Gardino (2003). However, as noted, even reputable authors are in dispute as to a final and definitive rule-of-thumb. Therefore, it is recommended that tests be conducted using screens, emulsions, and lab conditions where halftones will be printed. Once this is done, results with screen tints, halftones, duotones, and even process color will be much more pleasing to the eye.

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*This is a juried article*



# PDF Portfolios: A Viable Format for Student Designers

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## Introduction

Adobe Acrobat software is a powerful tool that can enable graphic design students to generate high-quality digital portfolios. Portable Document Format (PDF) files can be efficiently customized, distributed inexpensively, and yet they can maintain the visual impact of a traditional print portfolio. This article will examine how PDF portfolios can benefit design students when they are seeking professional employment and provide an introduction to building digital portfolios utilizing key features in Adobe Acrobat 7 Professional.

## The Power of PDFs

PDFs have a strong presence on the Internet and are commonly found on both MAC and PC platforms. Help files, installation guides, and order forms are all disseminated in PDF format. PDFs are a proven solution for accessibility and distribution of files worldwide. Ease of dissemination of files is augmented by the free distribution of Acrobat Reader via the Internet. The original appearance of graphics and typography is maintained on any computer display. PDFs can be generated from many common programs, including Microsoft Office, or through the printing options menu on many computers. After original documents are converted to PDFs, Acrobat 7 can be used to enhance the visual presentation and structure of the portfolios.

## Formatting Advantages

Digital portfolios can enhance traditional print portfolios. However, graphic designers need both types of portfolios to remain competitive in today's digital age. Traditional portfolios maintain a place in the job interview process, but digital portfolios have added purpose. A digital portfolio can accompany a resume and cover letter. Employers are able to view the quality of work and scope of the student's abilities prior to and during the interview process.

There are several distinct advantages to creating PDF portfolios. Graphic design students can:

- Adapt digital artwork files with minimal instruction.

- Control the presentation environment and viewing order.
- Customize portfolios for individual situations.
- Maintain flexibility in distribution and format.
- Protect design pieces from unauthorized use.

The creation of digital portfolios in PDF format does not necessitate the use of software that may be completely unfamiliar to students, such as Macromedia Dreamweaver or Microsoft PowerPoint. A majority of design students have a familiarity with Adobe's user interfaces from their experiences in using the Creative Suite. Web development and design skills are a tremendous benefit to have, but unless students have a command of this technology, it can work against them. If students build websites that are not portfolio quality, those sites can detract from the showcasing of their graphic design abilities and can ultimately effect the outcome of any job search.

Individual portfolio pieces can be converted into PDFs within minutes (if not seconds) by exporting them as PDFs from their native applications. Once the files are opened in Acrobat, presentations can be set to open in full-screen mode and automatically cycle through the portfolio pages. In full-screen mode, the viewing order and surrounding environment (a solid black background) are controlled by the PDF file settings. Portfolios can be displayed on any computer with Acrobat Reader or other PDF viewers, all of which protect the aesthetics and legibility of the artwork. Plus, PDFs can be customized for specific job opportunities with efficiency by rearranging or deleting pages within a copy of the original portfolio.

PDF portfolios have the flexibility of being distributed on CD, sent via e-mail, or posted online. If the portfolio is formatted on CD, Acrobat Reader software can also be distributed on the CD. A PDF sent through e-mail needs to have a small file size because e-mail servers have file size restrictions and storage limitations. Online PDFs may be downloaded to a computer or displayed within many web-browsers. If the PDF is downloaded, there may be an initial wait, but there will be no delays for viewing the PDF

as there can be when viewing the same file from an online source. Repeated delays could lessen the visual impact of the portfolio overall. Regardless of distribution format, security settings and passwords can protect students from having their designs reproduced without their knowledge. Acrobat can provide some safeguards from the inappropriate use or theft of a student's graphic design work.

## Building a Portfolio with Acrobat

PDFs can be directly exported from most graphics applications. Original document sizes and the orientation of artboards can vary from piece to piece. Export presets determine the image quality of the PDF files. Since greater image quality translates to a larger file size, the export settings should be suited to the formatting and distribution choices. If it is likely that the portfolio will be output through multiple methods, then determine the settings by the highest image resolution required. Lower quality variations can be generated through Acrobat Distiller, a program that is bundled with Acrobat 7.

Once all of the portfolio pieces have been exported as PDFs, the next step is to compile them into one document. Open all of the pieces in Acrobat. From the main menu, select "File > Create PDF > From Multiple Files" (Figure 1). Check the "Include all open PDF documents" box and then click on the "OK" button. A new PDF document will be generated. By default, this will be titled "Binder1.pdf," but the file should be renamed to reflect the designer's name.

Page ordering can be revised in the pages navigation tab to the left of the document. (If pages are not visible, select "View > Navigation Tabs > Pages" from the main menu.) Click and drag page thumbnails to rearrange the page ordering. Pages can be deleted by clicking first on the page thumbnail and then on the delete button at the top of this window.

These are simple and time efficient methods for customizing a portfolio for a specific job opportunity.

The next step is to set preferences for the presentation. Page transitions are accessed by selecting "Document > Set Page Transitions" from the main menu. The "Set Transitions" window will appear (Figure 2). Choices can be made for the effects used when changing from one page to the next, the speed in which the effect will occur, and the number of seconds each piece is viewed before automatically transitioning to another. After selecting "OK," the presentations settings can be previewed by entering Command-L on a Mac or Control-L on a PC.

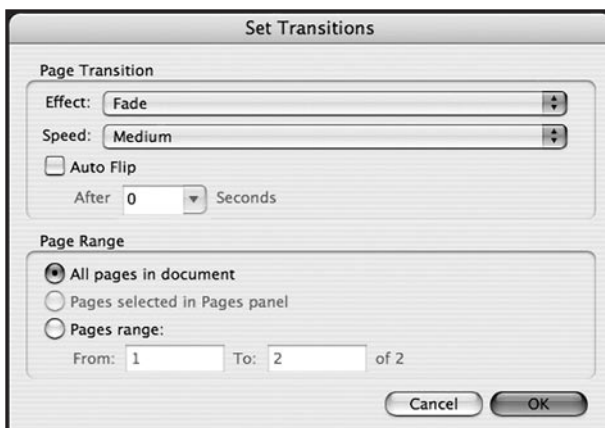


Figure 2

Additional preferences for the file's appearance upon its opening are accessed from the main menu by selecting "File > Document Properties." Within the document properties window, highlight the menu option for "Initial View," (Figure 3). This provides options for the document, the window, and the user interface. "Center window on screen" and "Open in Full Screen mode" are useful features for portfolios. In full screen mode, the pages are placed on a black background and all menus and windows will be hidden.

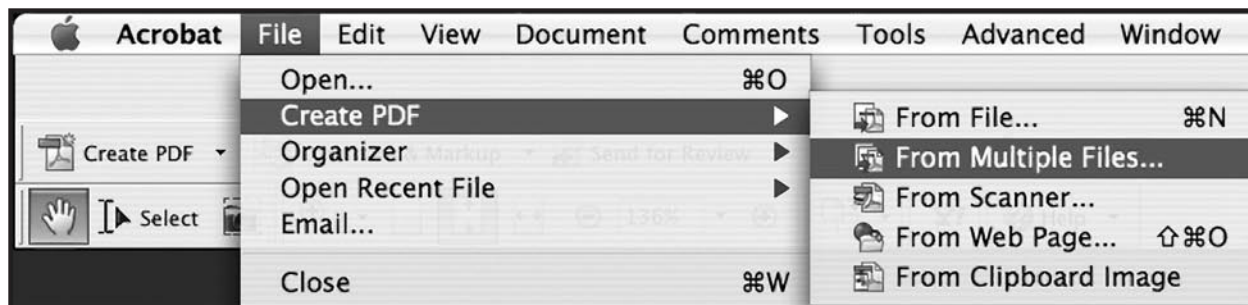


Figure 1

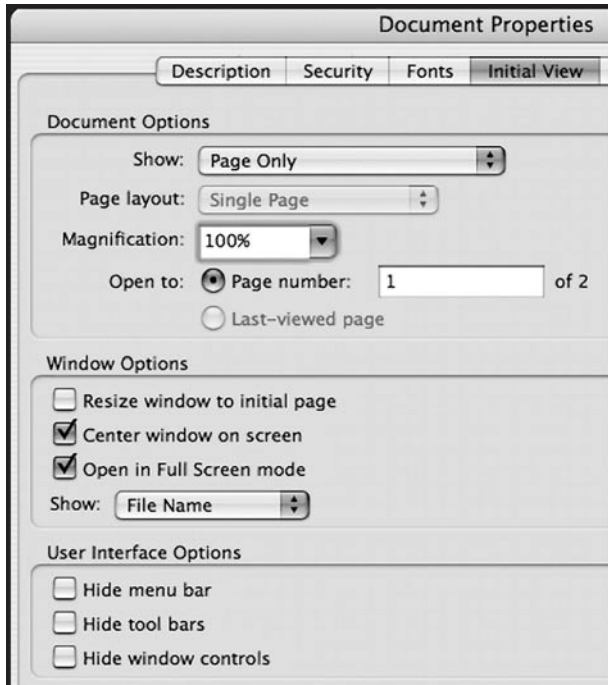


Figure 3

This can serve to focus the viewer’s attention by eliminating any distractions on the desktop. Centering on screen is effective for balancing the artwork, especially if there are various page dimensions.

Security settings are also accessed in the document properties window by highlighting “Security” menu option. Select “Password Security” from the security method pop-up menu. This opens the “Password Security – Settings” window (Figure 4) which is used to establish permissions for use of the document. A level of compatibility must be selected. If “Acrobat 5.0 and later” is chosen from pop-up menu for compatibility, then the file cannot be opened with Acrobat 4.0 or early versions of the software. Passwords can be set up to restrict usability or even require an entry of a password to view the document. Checking the box for “Restrict editing and printing of the document” is a reasonable precaution for students to take before distributing their portfolios.



Figure 4

## Conclusion

PDF portfolios are a viable solution for graphic design students seeking to showcase their talents. A command of PDF technology is rapidly obtainable for both educators and students who are already versed in graphics software, composition, and presentation skills. Beyond understanding the technology, students may consider building their portfolios with this specific medium in mind. According to Cynthia Baron (2004), "Make your PDF a project. A graphic designer should have a designed PDF, with a redesigned resume as a part of the package." By using Acrobat in the classroom, teachers can illustrate its possibilities and empower students to create professional-quality digital portfolios.

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# Middle and High School Communication Technology Curriculum that Addresses Mathematics, Science and Technology Education Standards

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At a national level, four new communication technology instructional units for the middle and high school classroom were disseminated and field-tested by the TECH-know Project, a program funded by the National Science Foundation (NSF) for the development of instructional materials. These four communication technology units are part of a total of 20 classroom units that were developed over a four-year period. North Carolina State University, the Technology Student Association (TSA), and the Departments of Public Instruction of North Carolina, Florida, Oklahoma, and Virginia were partnered to create, pilot, revise, and distribute student-centered instructional materials that are based on 20 TSA competitive activities. Within all 20 units, core science, mathematics, and technology education concepts and principles were identified, embedded, and correlated with the Standards for Technological Literacy as identified by the Technology for All Americans Project (ITEA, 2000), the National Science Education Standards, and the Principles and Standards for School Mathematics. For the purpose of this study, this evaluation focused only on the four TECH-know Project's Communication Technology Education units of instruction. These standards-based units included:

- 1) Cyberspace Pursuit, a middle school unit that explores technologies related to the Internet and webpage development.
- 2) Digital Photography, a middle school unit that explores the technologies and concepts behind electronic imaging.
- 3) Desktop Publishing, a high school unit that explores technologies related to digital printing.
- 4) Film Technology, a high school unit that explores the technology behind digital video and concepts for video production.

## Standards-Based Education Reform

It has been stated that the Twenty-First Century will require higher standards in education and greater accountability and achievement from teachers, schools, and their stu-

dents beyond a minimal comprehension of reading, writing, and the ability to perform simple mathematics (ITEA, 2000). These new requirements also concern recent U.S. Federal legislation of the 2002 law, No Child Left Behind (2002), that has redirected educational thinking and put into place a set of standards and testing plans to ensure that higher standards are met by 2014 (Meier & Wood, 2004). Because of these new standards, a proficiency in reading, mathematics, science, and technology is considered one of America's fundamental concerns of accountability in our public schools. A primary goal of this research was to assess the new TECH-know standards-based materials. These materials, developed for the 21st century student, contain objectives for learning math and science as well as communication technology content.

It is important to consider that standards can refer to both the goals of what should be done as well as the measurements of progress and quality toward that objective. Traditionally societies have developed methods (standards) of operation in order for its populace to live harmoniously within a society (Ravitch, 1995). "New members are made aware of codes of conduct deemed acceptable. Every society has a culture or a method of operating which is unique to it. To live harmoniously in a given culture, its members must be aware of the various codes of conduct that which are acceptable to that culture. It is through education that youth and new members are apprised of these facts" (Cummings, 1971, p.172). Knowing and understanding standards and how they are to be communicated to members of a society is equally as important to its populace.

## Communication Technology as Valuable Curriculum

It is important to recognize that the study of communication technology has been promoted, supported, and rationalized as part of technology education historically through numerous professional presentations, papers, workshops, meetings, and curriculum efforts (Robb and Jones 1990). Since this study focused on an evaluation of the student-centered materials developed for the four TECH-know communication technology objectives, it should be noted that, as a program of study, Communications Technology has been

consistently included in curriculum efforts of states that have adopted technology education-based programs (Robb and Jones 1990). A well-developed technology education program is one in which students will develop an understanding and be able to use information and communication technologies (ITEA, 2000). Historically, successful human societies have been evaluated by their capacity to communicate. How we communicate depends upon the creation of tools of communication so that people may communicate effectively and efficiently (Haynie & Peterson 1995). Communication technologies help us communicate and share information, thoughts, and ideas (Sanders 1997). The use of technology has enhanced human communications and affects numerous aspects of our daily lives, from enabling citizens to perform routine tasks to requiring that they be able to make responsible, informed decisions that affect individuals, our society, and the environment (ITEA 2003).

## The TECH-know Project

From 2001 until 2004, teachers from North Carolina, Virginia, Oklahoma, Pennsylvania, and Florida piloted, developed, and selected TECH-know Project units that were identified by the Standards for Technological Literacy, National Science Education Standards, Principles and Standards for School Mathematics, and TSA activities (Taylor, 2004). According to Ernst, Taylor, and Peterson in their 2005 article, *TECH-know: integrating engaging activities through standards based learning*, "Science, mathematics, and technology (SMT) literacy is vital to national interests, in particular to maintaining the economic health of the nation and the well being of its citizenry, making the success of SMT education especially important to everyone" (Ernst, Taylor, and Peterson, 2005, pg 15). During the pilot process, teachers administer a pre-test, post-test, and student perception surveys. The TECH-know Project collected data that supported the need for implementation and integration of these units in technology classroom across the country. Pre and post assessment by unit showed positive gains. Students also experienced positive gains in scientific, mathematical, and technological concepts in each TECH-know instructional unit (Ernst, Taylor, and Peterson, 2005). "Students were able to make connections to math, science and technology while enhancing their understanding of concepts embedding these activities" (Ernst, Taylor, & Peterson, 2005, pg 17). These results were considered favorable for field-testing the completed units.

During the summer of 2005, 20 middle and high school technology education teachers from nine states were provided an intensive one-week professional development workshop on the methodologies and contents of the TECH-know instructional materials. The teachers who were selected had no prior exposure to the materials. Representative states that expressed interested in the field test included North Carolina, Colorado, Connecticut, Georgia, Mississippi, Pennsylvania, South Carolina, Tennessee, and Wisconsin. The four field-tested communication technology units incorporated samples from both middle and high school classrooms in five states (Colorado, Connecticut, Pennsylvania, South Carolina, and Wisconsin), in both rural and suburban settings. The communication technology sample included five technology teachers, four males and one female, and total of 220 middle and high school technology education students. In all there were eight classrooms that included five high school and three middle school groups.

The methodology for this research assessed quantitative data collected from a stratified purposeful population of technology education classrooms in both middle and high school settings. The process began with a student assessment of their pre-content knowledge of Communication Technology units through criterion-referenced tests (CRT) based on standards for technological literacy and course rationale developed during the pilot study phase. The treatments were an application of standards based curriculum that has been developed over the past four years through a series of pilot testing and editing. The treatments were followed by a post-CRT on the content for each unit's content. These CRT instruments were developed and validated individually by each unit's writers and developers for their content rationale and appropriateness, and only altered to reflect each unit's fruition during the piloting phase.

The students in this sample were comprised of 149 male and 71 female members. The total number of middle school students in this sample was 105 and comprised of 64 males and 31 females. The total number of high school students was 115 and comprised of 85 males and 30 females.

The samples were limited to Technology Education programs in middle and high school classrooms participating in the TECH-know Project's Communication Technology Education units. These instructional units



required classrooms and labs with access to communication technologies including computers, access to the Internet, digital imaging and displaying equipment, printers, scanners, and associated materials.

The research question addressed: Are students learning mathematics, science, and communication technology content based on the pretest and posttest scores? In testing the null hypothesis [Ho], this study compared within-group variation for paired differences by using a t-test to examine errors in the before and after treatments looking for no effect at an alpha [ $\alpha$ ] confidence level of 95% and a probability P-value of 0.05 (Agresti & Finlay, 1997). The P-value probability was the primary reported result.

In comparing the sample's pretest and posttest scores, if the null hypotheses is true, students did not learn mathematics, sciences, and communications technology content. If a P-level greater than 0.05 is produced, the null hypothesis [Ho] would be plausible; the differences

between pretest and posttest scores would be too close to be statistically significant. A high P-level could also be caused by within-group variation. In either case, the null hypothesis [Ho] could not be rejected (Agresti & Finlay, 1997). A small P-value, on the other hand, is evidence against the null hypothesis [Ho] of no effect and provides support of the alternative hypothesis [Ha] (Agresti & Finlay, 1997) that students did learn mathematics, science, and technology content.

## Findings

Table 1 presents an overall summary of statistics of the sample's scores as grouped by each communication unit. An improvement in the overall posttest mean scores from the pretest mean scores is shown to be significant as presented in Table 2. The P-value of the paired t-test statistics for the pretest and post test scores of the sample's overall content of knowledge in each of the Communication Technology Units is smaller than 0.05 (CP < 0.0001, DTP < 0.0001, DP < 0.0001, FT < 0.0001), rejecting the null hypothesis of no

UNIT	n	Mean	Variance	Std. Dev.	Std. Err.	Median	Range	Min	Max	Q1	Q3
CP-Pretest	40	36.7	118.88	10.9	1.72	36	44	16	60	28	44
CP-Posttest	40	80.1	248.19	15.75	2.49	82	52	48	100	66	92
DTP-Pretest	47	39.31	373.78	19.33	2.82	36	68	12	80	24	56
DTP-Posttest	47	61.1	375.44	19.37	2.82	60	84	12	96	48	76
DP-Pretest	65	48.73	236.94	15.39	1.90	48	64	12	76	36	60
DP-Posttest	65	78.03	207.56	14.40	1.78	80	64	36	100	72	88
FT-Pretest	67	33.55	134.76	11.60	1.41	32	52	12	64	28	40
FT-Posttest	67	62.14	699.31	26.44	3.23	60	84	16	100	36	92

Table 1 Pretest and post test overall content sample scores distribution of summary statistics grouped by Communication Units  
CP= Cyberspace Pursuit, DTP= Desktop Publishing, DP= Digital Photography, and FT= Film Technology

UNIT	Diff.	Std. Err.	DF	T-Stat	P-value
CP	43.40	1.82	39	23.76	<0.0001
DTP	21.78	4.36	46	04.99	<0.0001
DP	29.29	1.73	64	16.9	<0.0001
FT	28.59	3.60	66	07.92	<0.0001

Table 2 Paired T statistics grouped by Communication Units.  
Alpha [ $\alpha$ ] confidence level of 95% and a probability P-value of 0.05  
Hypothesis test:  $H_0: \mu_1 - \mu_2 = 0$ ,  $H_A: \mu_1 - \mu_2 \neq 0$   
CP= Cyberspace Pursuit, DTP= Desktop Publishing, DP= Digital Photography, and FT= Film Technology

CP	Diff.	Std. Err.	DF	T-Stat	P-value
Technology	6.15	0.35	39	17.39	<0.0001
Mathematics	2.17	0.18	39	11.71	<0.0001
Science	2.52	0.2	39	12	<0.0001

Table 3 Paired T statistics for pretest and posttest for the Cyberspace Pursuit Unit sample scores grouped by technology, mathematics, and science  
Alpha [ $\alpha$ ] confidence level of 95% and a probability P-value of 0.05  
Hypothesis test:  $H_0: \mu_1 - \mu_2 = 0$ ,  $H_A: \mu_1 - \mu_2 \neq 0$

effect. The treatments in the Communication Technology Units had an affect on student scores.

An improvement in the overall posttest mean scores from the pretest mean scores in Cyberspace Pursuit is shown to be significant as presented in Table 3. The P-value of the paired t-test statistics for the pretest and post-test scores of the sample's overall knowledge in each content area of technology, mathematics, and science is smaller than 0.05 (Technology < 0.0001, Mathematics < 0.0001, Science < 0.0001), rejecting the null hypothesis of no effect. The treatment in the Cyberspace Pursuit had an affect on student scores in technology, mathematics and science.

An improvement in the overall posttest mean scores from the pretest mean scores in Desktop Publishing is shown to be significant as presented in Table 4. The P-value of the paired t-test statistics for the pretest and post-test scores of the sample's overall knowledge in each content area of technology, mathematics, and science is smaller than 0.05 (Technology < 0.0001, Mathematics < 0.0138, Science < 0.0001), rejecting the null hypothesis of no effect. The treatment in the Desktop Publishing had an affect on student scores in technology, mathematics, and science.

An improvement in the overall posttest mean scores from the pretest mean scores in Digital Photography is shown to be significant as presented in Table 5. The P-value of the paired t-test statistics for the pretest and post-test scores of the sample's overall knowledge in each content area of technology, mathematics, and science is smaller than 0.05 (Technology < 0.0001, Mathematics < 0.0001, Science < 0.0001), rejecting the null hypothesis of no effect. The treatment in Digital Photography had an affect on student scores in technology, mathematics, and science.

An improvement in the overall posttest mean scores from the pretest mean scores in Film Technology is shown to significant increase as presented in Table 6. The P-value of the paired t-test statistics for the pretest and posttest scores of the sample's overall knowledge in each content area of technology, mathematics, and science is smaller than 0.05 (Technology < 0.0001, Mathematics < 0.0001, Science < 0.0001), rejecting the null hypothesis of no effect. The treatment in the Film Technology had an affect on student scores in technology, mathematics, and science.

DTP	Diff.	Std. Err.	DF	T-Stat	P-value
Technology	3.27	0.64	46	5.04	<0.0001
Mathematics	0.93	0.36	46	2.56	0.0138
Science	1.23	0.27	46	4.44	<0.0001

Table 4 Paired T statistics for pretest and posttest for the Desktop Publishing Unit sample scores grouped by technology, mathematics, and science  
Alpha [α] confidence level of 95% and a probability P-value of 0.05  
Hypothesis test: H0:  $\mu_1 - \mu_2 = 0$ , HA:  $\mu_1 - \mu_2 \neq 0$

Content	Diff.	Std. Err.	DF	T-Stat	P-value
Technology	4.36	0.31	64	13.73	<0.0001
Mathematics	1.87	0.15	64	12.16	<0.0001
Science	1.07	0.16	64	6.72	<0.0001

Table 5 Paired T statistics for pretest and posttest for the Digital Photography Unit sample scores grouped by technology, mathematics, and science  
alpha [α] confidence level of 95% and a probability P-value of 0.05  
Hypothesis test: H0:  $\mu_1 - \mu_2 = 0$ , HA:  $\mu_1 - \mu_2 \neq 0$

Content	Diff.	Std. Err.	DF	T-Stat	P-value
Technology	4.29	0.59	66	7.16	<0.0001
Mathematics	1.47	0.22	66	6.52	<0.0001
Science	1.37	0.23	66	5.84	<0.0001

Table 6 Paired T statistics for pretest and posttest for the Film Technology Unit sample scores grouped by technology, mathematics, and science  
alpha [α] confidence level of 95% and a probability P-value of 0.05  
Hypothesis test: H0:  $\mu_1 - \mu_2 = 0$ , HA:  $\mu_1 - \mu_2 \neq 0$

## Conclusions

According to these findings, all four TECH-know Communication units of instruction had a significant affect on student's scores in communication technology, mathematics, and science content. A proficiency in reading, science, mathematics, and technology is considered one of America's fundamental concerns of accountability in our public schools (Meier & Wood, 2004). The No Child Left Behind law (2002), requires school programs, teachers and students to adhere to higher standards reading, science and mathematics by the year 2014 (Meier & Wood, 2004). Developing a sound curriculum that promotes literacy in those areas is critical. Science and mathematics education are characterized as theoretical, whereas technology education (TED) emphasizes constructive philosophies. The TECH-know Project developed co-curricular instructional materials that are closely aligned with foundational science and mathematics concepts. Their effectiveness will depend on marketing and dissemination nationally.

## Implications for Further Research

Extensive research and development preceded this study on the assessment of the affects of standards-based communication technology education units. The significant achievement by middle and high school students in these communication technology classrooms depended on the development of those quality materials as well as the professional development and training of those classroom teachers. Future research in the areas of communication technology and the development of instructional materials should incorporate statistical analysis as a key component of research as well as developing materials that incorporate core science, mathematic, and technology concepts and principles. It is essential to research the relevance of communication Technology Curriculums as well as their acceptance by students as a valuable resource in preparing them for the future.

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