ABSTRACT

POLSTON, KATHERINE P. Capabilities and Limitations of Print-on-Demand Inkjet Digital Textile Printing and the American Craft Niche Market. (Under the direction of Dr. Lisa Parrillo-Chapman).

The objective of this research is to determine the capabilities and limitations of print-on-demand inkjet digital textile printing as perceived by niche market users. The research questions are (1) To determine the capabilities and limitations of inkjet digitally printed textiles as measured by the opinions of a group of users; (2) To determine if there is a difference in perceived capabilities and limitations of inkjet digitally printed textiles per niche market users. Users of a print-on-demand inkjet digital textile print bureau were surveyed using a quantitative survey instrument. User demographic data was collected, as well as aspects concerning the capabilities and limitations of print-on-demand inkjet digitally printed textiles. The aspects measured are; Color Control, Time Needed for designs, Turn-around Time for Order, Fabric Choices, Quality of Print, Quality of Fabric, Printable Fabric Width, User Skill Level in Computer Aided Design Software, User Skill Level in Color Control and User Skill Level in Creating Repeat Patterns. Users self-identified themselves as one of four niche market user groups; Crafters, Designers, Artist/Artisan and Small Business Owners/Entrepreneurs. Results indicate that there are no perceived limitations aside from User Skill Levels. User Skill Levels were predominantly below average and differed significantly between niche market user groups. This research is significant as it provides insight into the users of print-on-demand inkjet digitally printed textiles.

Capabilities and Limitations of Print-on-Demand Inkjet Digital Textile Printing and the American Craft Niche Market

by
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DEDICATION

This work is dedicated to my parents; Mary Jane Burson-Polston and Mike Polston, for believing in me and giving me their support and unconditional love. Their guidance and encouragement made this research possible. I would also like to dedicate this work to my husband, Robert Jordan Hunt, for travelling with me on this road and offering me his love and support.

BIOGRAPHY

Katherine P. Polston was born November 28, 1984 in Austin, Texas. She is the middle child and eldest daughter of Mary Jane Burson-Polston and Mike Polston. She was raised in Austin, Texas. She attended McCallum High School and graduated in the top 10 percent of her class in 2002.

In August of 2002, Katherine began her higher education in the Mechanical Engineering Program at the University of Texas at Austin. She added Textiles and Apparel as a second major in her second semester before switching to Textiles and Apparel Design as her sole major. Katherine graduated and received her Bachelor's of Science in Textiles and Apparel Design in 2006.

In August of 2009, Katherine began her studies at North Carolina State University College of Textiles in the Department of Textile and Apparel, Technology Management. She was awarded a research assistantship with Dr. Lisa Parrillo-Chapman, aiding in the research of inkjet digital textile printing. She has widened her focus to include the teaching of computer aided design technology, color management and inkjet digital textile printing.

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CHAPTER 1: INTRODUCTION

1. Introduction

Inkjet digital textile printing has the potential to replace some aspects of conventional textile printing methods, as well as create new textile product markets (Dehghani, Jahanshah, Borman, Dennis & Wang, 2004).   Inkjet digital textile printing reduces the cost and time of print sampling, two factors that provide a competitive advantage for designers and textile companies that strive to be the first to market. The increase in number of printable colors and higher resolution capabilities of inkjet digital textile printing produces photo-realistic and nuanced gradient prints. Inkjet digital printers also permit an unlimited size of repeat and enable textile designs to be engineered for the shape and/or size of the finished product (Jennings, 2007). Designs are printed clearly and there is no need for color reduction. The capability of inkjet digital textile printing to print photo-realistic prints offers a larger and more novel variety of textile prints, satiating customers' needs for new and unique products (Moser, 2004).

The unique capabilities of inkjet digital textile printing enables niche businesses, such as those catering to the crafter market, to differentiate their product by having novel, unique and interesting print designs. The flexibility and customization capabilities of digital textile printing presents opportunities for mass customization, limited editions and one of a kind pieces (Fralix, 2006). This technology can benefit niche businesses through diversification of product offerings and quick response to the market, two key competitive advantages for companies. These capabilities open opportunities for American entrepreneurs and preexisting companies. Inkjet digital textile printing also allows companies to meet consumer demand from niche markets. Figure 1 (Tyler, 2005) demonstrates the various capabilities inkjet digital textile printing provides in flexibility, process enhancement and innovation. Inkjet digital textile printing enables technological innovation through novel inks and nanotechnology. Companies utilizing inkjet digital textile printing are more flexible throughout the product lifecycles. Smaller product runs, reduced setup costs and the ability to change or modify the print design easily are some examples of product design flexibility made possible by inkjet digital textile printing. Inkjet digital textile printing enhances the product design and manufacturing process through customization options, innovative design capabilities, reduced stock levels and waste.

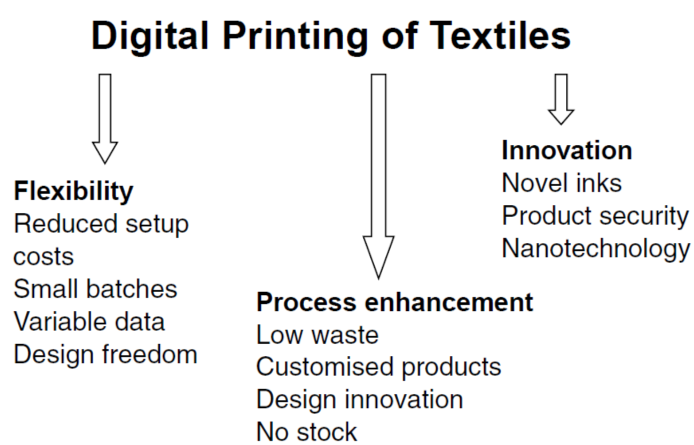


***Figure 1*: Commercial impacts of textile digital printing (Tyler, 2005)**

1.1. Research Question and Objectives

The research question for this study is:

1. What are current capabilities and limitations of print-on-demand inkjet digital textile printing as perceived by niche market users?

Two research objectives were developed to measure the capabilities and limitations of print-on-demand inkjet digitally printed textiles as perceived by niche market users. The two research objectives are:

1. To determine the capabilities and limitations of print-on-demand digitally printed textiles as measured by the opinions of a group of niche market users. The aspects measured were:

    a. Color Control
    b. Time Needed for Designing
    c. Turn-Around Time for Order
    d. Fabric Choices
    e. Quality of Print
    f. Quality of Fabric
    g. Printable Fabric Width
    h. User Skill Level: CAD Software
    i. User Skill Level: Color Control
    j. User Skill Level: Creating Repeat Patterns

2. To determine if there is a difference in perceived capabilities and limitations of print-on-demand inkjet digitally printed textiles per self-identified niche market user types.

a. Crafters

b. Designers

c. Artist/Artisan

d. Small Business Owners/Entrepreneurs

The opinions of a group of users were measured using a quantitative survey instrument to determine how aspects of inkjet digital textile printing utilized in a print-on-demand business structure are perceived by users. Six aspects of inkjet digital textile printing were measured by ranking the positive, neutral or negative impacts of creating custom fabric. Aspects measured included cost, production and design time, product quality and fabric availability. Participants were asked to self identify as one of four niche market categories: a crafter, a designer, an artist/artisan, or a small business owner/entrepreneur to determine if there is a difference in perceived capabilities and limitations of inkjet digitally printed textiles per self-identified user type. Users' own self-assessed skill levels pertaining to technological and design aspects of inkjet digitally printed textiles in color control, computer aided software systems and creation of repeat patterns were measured to ascertain the capabilities and limitations of the technology.

1.2. Relevance

The results of this research will assist in determining aspects of print-on-demand inkjet digital textile printing that niche market users perceive as beneficial and the aspects needing improvement. Findings from this research will provide valuable feedback for vendors and manufacturers of printing equipment, CAD, and color management systems. This research will also benefit educators teaching future users of the technology by defining areas of skill that could be improved. This research concerns perceived capabilities and limiations of inkjet digital textile printing in particular regards to the 'crafter' and other niche markets in America. The results of this research will identify how niche market users of print-on-demand inkjet digitally printed textiles perceive themselves; i.e. as crafters, designers, artists/artisans or small business owners/entrepreneurs. It will also be determined from this research whether there are areas within the inkjet digital textile printing market that could use improvement in terms of user skills or accessibility. Others who will benefit from this research include American textile finishers and printers who are looking for ways to increase their competitive advantage in the textile and apparel industry through specialization in inkjet digital textile printing technology. Entrepreneurs will also benefit as the research results demonstrate the capabilities and potential of the inkjet digital textile printing market in relation to niche market users and market oppurtunities. Future research in the inkjet digital textile printing market will be able to expand on the initial findings of this research.

CHAPTER 2: LITERATURE REVIEW

2. Literature Review

This chapter covers the comprehensive review of the literature conducted on inkjet digital textile printing technology and on the craft and niche markets in America. Results from the literature review enabled the principal investigator to understand the needs of the businesses and consumers of this market in order to create the survey instrument. The survey instrument queried participants on the technological capabilities and limitations perceived by different niche market user groups of print-on-demand inkjet digitally printed textiles. Sections 2.1.1.-2.1.3. cover inkjet digital textile printing with an overview of the hardware, software and known capabilities and limitations. Section 2.1.4. covers demand for inkjet digital printing with an overview of niche markets in America and the American craft market. Section 3 covers the methodology used for the creation of the survey instrument and statistical analysis of results.

2.1. Inkjet Digital Textile Printing

Inkjet digital printing of textiles is based on inkjet printing technology developed for large scale advertising printing (Dawson, 2004). Inkjet digital textile printing is currently used most often for sample prints and small order lengths or short runs. Inkjet digital textile printing is more time, money and labor efficient than screen printing for short-runs and product sampling (Ross, 2001). The printed textiles market is facing the same pressures to innovate and streamline the product design and manufacture process as the rest of the textile and apparel industry. In 2003, 11-13% of the international textile manufacturing products were produced by printing and throughout these various printing methods over half of the total production time was invested in preparing printers and sampling the product (Choi, Yuen, Ku, & Kwan, 2003). By implementing inkjet digital textile printing technology for sampling, costs associated with this part of the product design process will be minimized. Companies will be better equipped for meeting changing market requirements such as individualism, quick response, shorter fabric runs, rapid fashion, low storage costs, design copying, as well as environmentally friendly wear properties and production process (Choi et al., 2003). Inkjet digital printing of textiles provides opportunity for the textile market to innovate and streamline the process from product design through to manufacture. This would not be possible without the advancements that have been made in the technology concerning inkjet printheads, machinery and colorants used and the supporting software systems. Figure 2 (Choi et al., 2003) demonstrates the difference between the production methods and times of conventional textile printing versus inkjet digital textile printing. Comparing the time-span of conventional textile printing to inkjet digital textile printing makes readily apparent the time saved by implementing inkjet digital textile printing. The sampling and production process is reduced from 9-11 weeks to one week. The longest process in conventional textile printing is the preparing of screens and color matching; this process usually takes six-eight weeks. Screen preparation and color matching processes are removed from the print sampling and production process when utilizing inkjet digital textile printing.

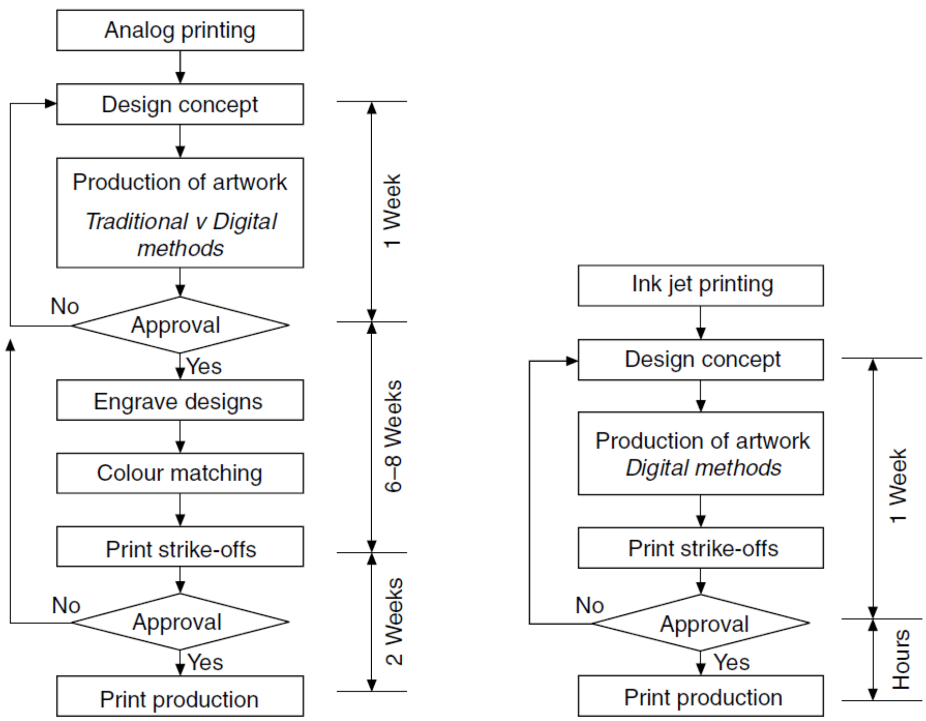


***Figure 2*: Screen print and digital print production routes (Choi et al., 2003)**

2.1.1. Overview of Inkjet Digital Textile Printing Technology

Inkjet printing is a non-impact printing technique in which colorants are ejected, either by dropping or spraying, through the printhead nozzles onto the substrate to be printed (Keeling, 1981). Inkjet digital textile printing integrates traditional textile printing components, such as colorant formulation and substrate preparation, with technology such as inkjet printer machinery, inkjet printheads and the supporting computer software systems. This section will discuss in detail the hardware, colorant and substrate properties and software systems that make up inkjet digital textile printing technology and will conclude with an overview of the capabilities and current limitations of inkjet digital textile printing technology. Inkjet digital textile printing systems have improved reliability and efficiency in a short span of several years. Aspects of inkjet digital textile printing that are being addressed for improvement in the industry are print quality and resolution, production speed and costs (Glover, 2004). To achieve the higher printing speeds needed to compete with and/or replace conventional printing systems and ‘transform’ the printed textile market, inkjet printer reliability must continue to improve among the three main parts of printer; the printheads function and maintenance, colorants formulation to avoid clogging of printheads, and redundancy of printhead nozzles to allow for replacement of non-functioning ones, as well as for randomization of defects to make them less noticeable (Work, 1998).

2.1.1.1. Machine

An inkjet digital textile printing system is typically comprised of four basic components: hardware/printer, ink and colorant formulation, media/substrate, and software for communicating the print repeat and color to the printer (Choi et al., 2003). A wide variety of inkjet printheads exist but the two main types used in the inkjet digital printing of textiles are continuous ink-jet or drop-on-demand (DOD) printheads, such as bubble or thermal heads, and piezoelectric heads.

Inkjet printhead technology has been used in the textile and apparel industry since the 1960’s and in the 1970’s was used for printing carpets using continuous inkjet printheads (Cahill, 2006). The technology improved in the 1990s to be applied to smooth surfaces, such as banners and signs, but was limited in use for textile substrates. The predominate uses for textile applications are for sampling products for photo shoots, flags and small run niche products, such as silk ties (Tyler, 2005). The technology required for inkjet digital textile printing has seen myriad developments in both the quality and quantity of commercial machines, colorants and software. While the basic understanding of print repeats, colorants, color control and reproduction, and print quality is similar for both conventional printing and digital printing, there are fundamental differences beginning with inkjet printhead technology.

The main component of inkjet textile digital printers is the printheads. Since the 1990's, printhead mechanisms have been engineered to produce smaller ink drop sizes and therefore increase the resolution of prints. A wide variety of printheads are utilized in the textile inkjet printing field, each with its own set of advantages, disadvantages and applications. The two major inkjet printhead technologies used are Drop-On-Demand (DOD) and Continuous Inkjet (CIJ) (Freire, 2006). Each inkjet printhead type has several types of subsets of heads that are detailed in the Figure 3 (Tyler, 2005). DOD inkjet printheads have the widest variety of sub-types. Piezoelectric printheads are the printhead type used most often in inkjet digital printing of textiles.

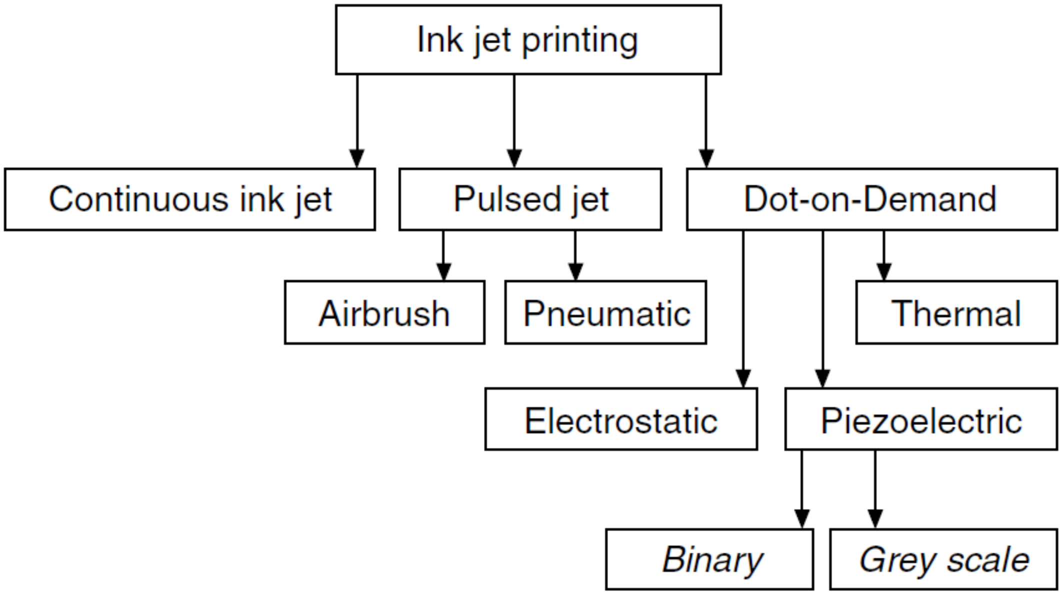


***Figure 3*: Classification of inkjet printing technologies for textiles (Tyler, 2005)**

Dot-On-Demand or Drop-on-Demand (DOD) inkjet printheads are the most widely adopted type of printhead for digital textile printing. A DOD printhead operates by putting a drop of ink or dye wherever there is a demand for ink on the substrate to create the final print (Hunting, Puffer & Derby, 1995). DOD printheads operate on a simple binary command of either firing or not firing a drop of ink. The ink droplet is drawn to and deposited on the substrate surface by the force of gravity. Drop sizes are measured using picoliters (pl), that are the equivalent of 10^{-12} of a liter. Usually drop sizes are 20-30 pl and are reducing to 10pl and even 1pl (Tyler, 2005). Smaller ink drop sizes are able to achieve higher print resolutions although ink coverage and deposition rate on the substrate surface is reduced. Piezoelectric DOD inkjet printheads are capable of producing variable sized ink droplets, which allows for better print quality (Sakai, 2000). Among DOD inkjet printhead sub-types, piezoelectric inkjet printheads are the most widely adopted for textile applications. Piezoelectric printheads operate by the distortion of a piezo material within the printhead under an electric field or when an electric field is deformed. When the electric field is turned on the volume of the ink chamber is reduced, forcing out a drop of ink through the nozzle to be dropped onto the fabric surface. Once the electric field is turned off, the chamber's volume returns to normal, sucking the ink back through the nozzle into the chamber while also drawing more ink in from the ink supply (Tyler, 2005). Piezoelectric printheads have greater control over drop production compared to thermal printheads. Piezoelectric printheads are able to print a variety of drop size and can print at higher production rates. Piezoelectric printheads also last longer than thermal printheads and can use a wider variety of ink formulations because the ink is not heated.

Continuous inkjet print heads (CIJ) are used for some inkjet digital textile printing but are not the most widely used in textile applications. CIJ printheads operate by ejecting a continuous jet of ink from the printhead nozzle that breaks apart to form a stream of ink droplets within a short period of time (Le, 1998). The movements of the ink droplets are controlled via an electrostatic charge and are deposited either onto the substrate surface or directed to a recirculation system by an electric field (Dawson, 2004). CIJ technologies were the first to be applied to textile digital printing but have not been as widely adopted as DOD printheads. CIJ printheads are able to print at higher speeds than DOD piezo- and thermal-printheads. CIJ printheads are therefore the most likely to be developed for inkjet printing of textiles at high production rates (Dawson, 2004).

2.1.1.2. Software

The digital revolution has been ongoing in the textile industry since the invention of Jacquard looms and binary code pattern cards. The application of computer technology to the textile design and manufacture process has been driven largely by reasons of economy and reduction of time spent on product development (Treadaway, 2004a). CAD software systems are utilized throughout the product development and design processes in the apparel and textile industry (Ulrich, Anderson-Connel & Wu, 2003). Current computer aided design (CAD) systems have been used for textile design since the 1970's. While there was initial resistance to technology by designers, newer generations of textile and apparel designers view technology, such as computer aided design software, as freeing, allowing them to design more creatively and efficiently (Nicoll, 2006). The user-friendliness of recent software systems and reduced hardware and software costs is providing wider access to design and production technology (Treadaway, 2004a). There is a wide variety of CAD systems available ranging from free on-line systems such as GIMP (GNU Image Manipulation Program) to off-the-shelf software such as Adobe Photoshop and industry specific systems such as Lectra Kaledo Print. With inkjet digital textile printing and digital design capabilities textile designers are no longer required to reduce the number of colors in a design. Without the traditional restraints on the development and creation of textile prints the designer is free to create unhindered. Most textile designs remain in the digital world until printed; this makes it easier to manipulate images and engineer textile designs for the final three dimensional products (Burton, 2005), and create unique and novel textile products. Digital files used for inkjet digital textile printing must be acceptable across different operating platforms, such as Mac or Windows (Parsons & Campbell, 2004).

CAD software systems aid in designing and storing of the textile design, as well as communicating color, resolution and placement and size of the ink drop to the printer. CAD software and digital color management is an essential component in the commercial success of an inkjet digitally printed textile product (Henry, 2004). Print-driver software in combination with color calibration software allows the user to determine the amount of ink deposited on different substrates to ensure the best image quality (Dawson, 2001). Software systems manage color reproduction across various substrate types through calibrations and color profile creations. A variety of color management software packages are available on the market today, each with different degrees of profiling and color management capabilities, as well as various price points depending upon the software's capabilities (J.R. Campbell, 2006). Color management software used for inkjet digital textile printing allows users to create the color gamut, or range of printable colors, for each printer, colorant and fiber and fabric type (Gordon, 2001). Color management software must also be able to determine if colors within the digital version of the print design are reproducible by the printer, colorant and substrate selection. Color management software systems are able to create and manage color profiles ranging from third-party color profiles, vendor supplied color profiles and user-created color profiles. The International Color Consortium (ICC) color profile is a third-party standardized format for the color gamut and color reproduction capabilities of digital devices such as digital cameras, scanners and computer monitors (Gordon, 2001).

Raster Imaging Processing (RIP) software is a printer driver which converts image data (by rasterizing the image) to be sent to the printer (J.R. Campbell, 2006). RIP software systems control the printer and colorant and there is a wide range available for various printer types. RIP software systems used in textile printing operations can also have color management capabilities, as well as textile print set-up capabilities such as color separation, repeating print motifs and print layout (J.R. Campbell, 2006). Color management and RIP software systems for inkjet digital textile printing are able to perform color calibrations, create color catalogs and palettes, enable custom color profiling of a variety of fabric and colorant type and some RIP systems allow for the creation of a visual representation of color gamut (J.R. Campbell, 2006). Choosing a software system for design, color management and printer operation is fundamental to fulfill inkjet digital textile printings full potential.

2.1.1.3. Colorant

Colorants in inkjet digital textile printing are dye or pigment-based inks and must meet the same quality standards as conventionally printed textiles such as wash, color and crock fastness (Daplyn & Lin, 2003). Most inkjet digital textile printers are based on the four color CMYK (Cyan, Magenta, Yellow and Black) color system. To extend the printable color gamut many inkjet digital textile printers operate with 7-12 colors (Gordon, 2001). The CMYK color system is a process color system rather than spot color system used for conventional textile printing (Ross, 2001). Figure 4 (Presgrave & Provost 1996) demonstrates the difference in color gamut between a four color system and an expanded eight color system. There is a noticeable difference in gamut size in the red, violet, green, cyan and blue color ranges between a four color system and an eight color system. With an addition of four colors the user is able to print a wider variety, or gamut, of colors.

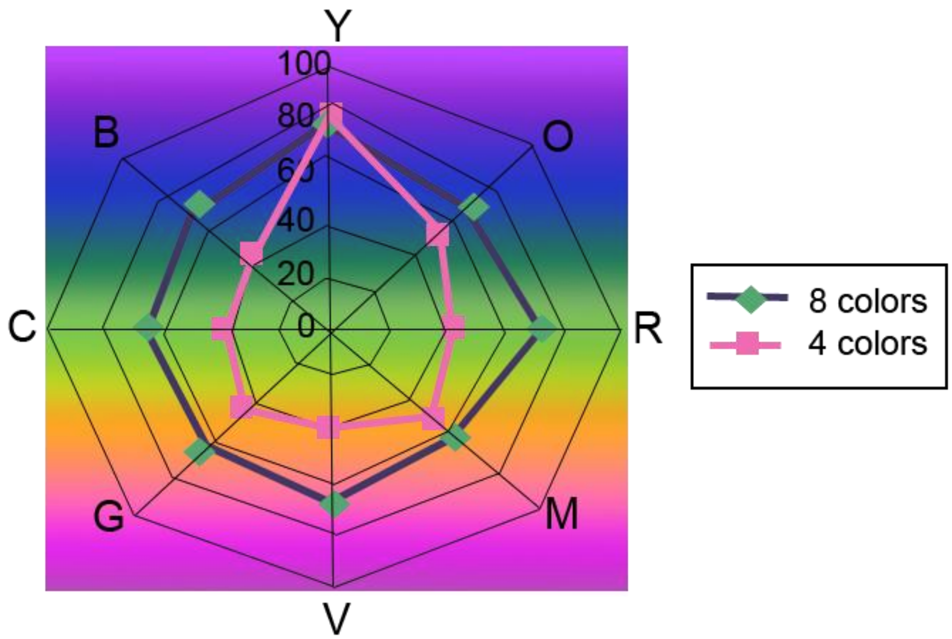


***Figure 4*: Color gamut comparison of 4 color system to 8 color system (Presgrave & Provost 1996)**

Colorant particles are combined with a carrier medium, which is either water or water-based with the addition of organic solvents and co-solvents. Dyes are formulated by dissolving colorants in the carrier medium. This differs from the formulation of pigments in which insoluble minute pigment particles are suspended in the carrier medium (Sayed, 2003).

Colorants used for inkjet digital textile printing must be milled and filtered to a much finer degree than required for traditional textile printing and must be formulated to specific standards of viscosities, surface tension, electrical conductivity and how it responds to different temperatures (Choi et al, 2003). Colorants must also hold up to long shelf lives while being shipped or stored before printing and once within the printer must be compatible with the inkjet printheads and not corrode or block the printheads. Colorants for textile digital printing must also absorb into the fabric quickly and evenly, meet color expectations and requirements and also meet standard wear and tear qualities such as wash and light fastness (Choi et al., 2003). Colorants must also not adversely impact the textile's tactile properties such as hand (Tincher, Hu, Li, Tian & Zeng, 1998). Inkjet textile colorants have much lower viscosities than textile screen printing colorants which are more viscous and akin to a paste. The amount of a colorant's bleeding and penetration into the textile substrate are very different between inkjet colorants and screen printing colorants. Therefore the designer and printer operator must take into account the ink, textile and printing system when setting up a textile to be printed to achieve the desired hand, color and color fastness (Work, 1998)

There are four main types of colorants used for inkjet digital textile printing and are similar to colorants used for conventional textile printing; reactive, acid, disperse and pigment (Byrne, 2004). Water-soluble dye-based inkjet colorants are reactive, acid and disperse dye-based inks. Disperse dye-based inks are a colorant type utilized in inkjet digital textile printing with polyester fibers. Reactive and acid dye-based inks are capable of printing on a wider variety of fibers than disperse dye-based inks. Reactive dye-based inks are capable of printing on cellulosic fibers such as cotton and some protein fibers such as silk in vibrant colors and excellent wash fastness (Blank et al. 2004). Acid dye-based inks are capable of printing on protein fibers such as silk and wool, as well as polyamide fabrics and also print vibrant colors with good wash fastness (Blank et al. 2004). Inkjet printing with either acid or reactive dye-based inks requires that the textile substrate must be pre-treated in order for the dyes to penetrate and fix to the fibers. Prepared-for-Print or PFP fabrics are available on the market to be used for inkjet digital textile printing (May-Plumlee & Bae, 2005). Once printing is completed the fabric must be steamed to set the inks and the excess ink must be rinsed out. Colors in reactive and acid dye-based inks experience some amount of color shift upon steaming. Figure 5 (Gordon, 2001) demonstrates the color change reactive dye-based inks undergo after steaming and washing. Colors in the yellow and green color range exhibit a drastic change in color gamut upon steaming and washing whereas other colors such as red and turquoise do not exhibit such as drastic a color shift.

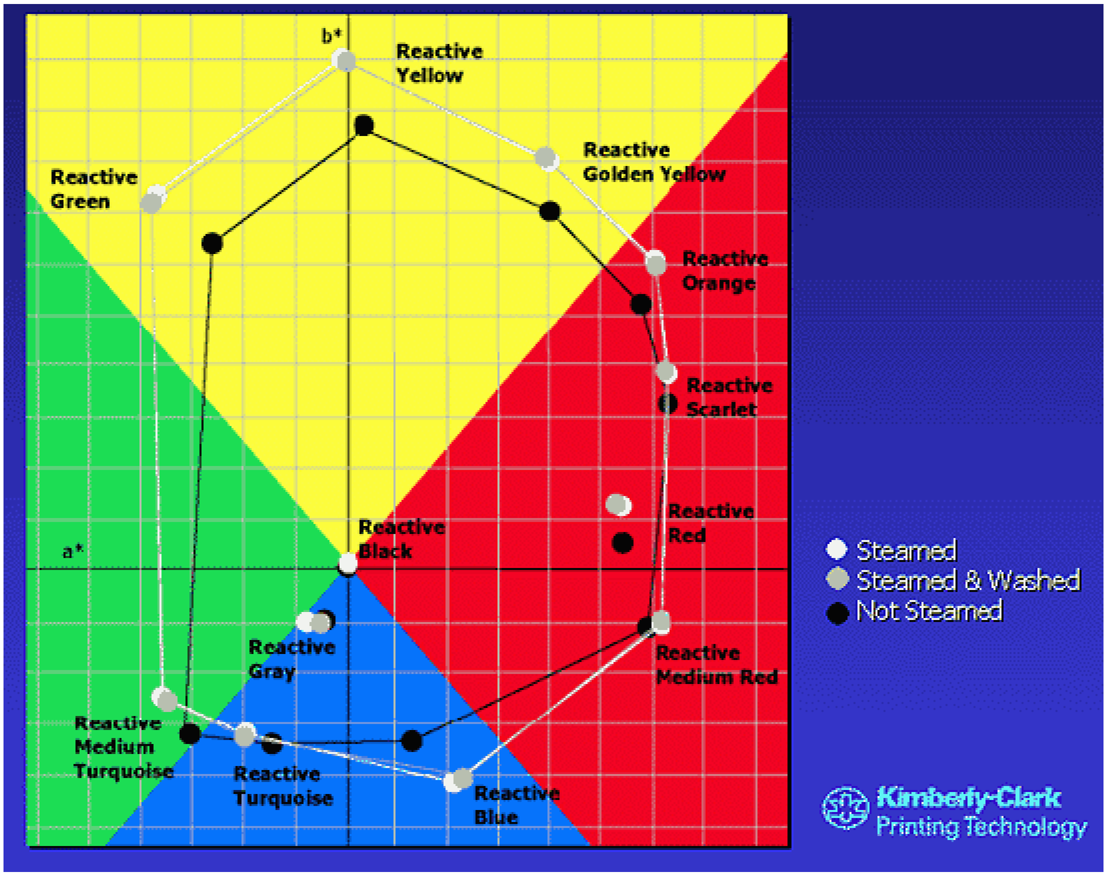


Figure 5**: 12-Color reactive ink set color gamut showing enhanced color space provided by steaming and washing (Gordon, 2001)**

When printing with acid or reactive dye inks the textile substrate must be pre and post-treated to allow for proper deposition and absorption of the ink and to allow the ink to be fixed onto the fabric. Pre-treatment of textiles to be inkjet printed is necessary for color fixation and to control colorant penetration and image quality (Blank, Chassagne & Reddig, 2004). Upon printing the textile must be heated or steamed to set the dye and then washed and dried to remove any excess unfixed dye. This process of pre- and post- treatment is similar to those used for rotary and screen printing. In textile printing pigments account for nearly half of all printed textiles (Sayed, 2004). Pigment-based textile colorants wide adoption by the textile and apparel industry can be attributed to the capability for printing on a wide variety of fiber types, cost and ease of application (Blank et al., 2004). A relatively new entry to inkjet printing, pigment colorants were introduced in mid-1996 to the inkjet printing market capable of high-resolution process color pigment printing for improved light fastness on paper and film substrates (Work, 1998). Pigments that are formulated for inkjet printing require smaller particle sizes that are able to fit through the inkjet nozzle and are encapsulated within a binder material (Dawson, 2001). Pigment printing requires a binder to allow it to adhere to the fabric and in conventional textile printing the binder is combined with the pigment in the printing paste. In inkjet digital textile printing with pigment-based inks the binder is applied in the ink or a separate application after printing (Sayed, 2004). Smaller pigment particles allow for better color gamut, gloss, light fastness, improved stability and optical density (Bugner & Bermel, 1997). After deposition onto the substrate surface the fabric is dry heat set. This method of setting or curing melts the binder material that attaches the pigment particle onto the substrate surface (Blank et al., 2004). Inkjet digital textile printing with pigment-based colorants requires no pre-treatment of the fabric and no wet post-processing such as steaming and washing. Pigment-based colorants with the binder already combined in the printhead function best with piezoelectric printheads as printheads that use heat would set the pigment and binder in the inkjet printhead nozzle ruining the printhead (Dawson, 2001). Just as with traditional textile printing quality control of the ink formula must be standardized and consistent so that inks can be replenished with no need to recalibrate the printer or cause color inconstancy for clients. Pigment-based colorants are currently available from a variety of ink providers, including DuPont, Huntsman Textile Effects, BASF and a newer formulation from Yuhan-Kimberly (King, Garland, Pagan, & Nienke, 2009). The nano-pigment inks manufactured by Yuhan-Kimberly use particles 70-120 nanometers in diameter depending on color and formulations include a binder or crosslinking agent to enable fixation (King, et. al., 2009). While the color gamut for pigment inks are smaller than that of a reactive or acid based inkjet textile colorants, the newer nano-pigment inks have a larger color gamut compared to that of other pigment-based colorants currently on the market for inkjet textile printing (King et al., 2009).

Colorants used in inkjet digital textile printing allow for printing thousands of colors across many different fibers and substrates. As with any technology, inkjet textile colorants are researched and improved upon. The capabilities and technology of inkjet digital textile will be covered in depth in Section 2.12.

2.1.2. Capabilities

Inkjet digital textile printing adoption by the textile and apparel industry is pulled by demand for personalization and rapid response, short print runs, environmentally-friendly processes and costs savings by reducing inventory levels (Gregory, 2004). Predominantly used for product development sampling or one-of-a-kind exclusive items inkjet digital textile printing is drawing wider acceptance for customization and niche market opportunities (King et al., 2009). In 2001, inkjet digital printing of textiles was no greater than 0.25% of the market and by 2004 the percentage of the market had grown to around 1% (Dawson, 2001; Eckman, 2004). The textile and apparel industry is also offering a wider variety and more differentiated selection of products and market to the individual customer (Fralix, 2006). Inkjet digital textile printing is capable of printing nuanced photo-realistic designs, large ranges of halftones, exclusive haute couture and limited edition products, and print-on-demand and mass customized textiles and apparel (Dawson, 2000). Inkjet digital textile printing can be combined with conventional textile printing for short runs of product for replenishment of inventory, as well as changes in color ways and design details if an order changes on short notice. An added benefit of inkjet digital textile printing is the improved control over the amount of colorant applied to the fabric, this leads to a better fabric hand, reduces chances of ink chipping or flaking off as the fabric moves and less ink waste (Sarma, 2004). Water and energy use is also lower for inkjet digital textile printing when compared to conventional textile printing methods, making inkjet printing a more ecologically friendly textile printing option (Choi et al, 2003).

The unique capabilities offered by inkjet digital textile printing allow for new business models and market opportunities in addition to innovative designs and artistic expression in textile printing.

2.1.2.1. Print-on-Demand (POD)

Print-On-Demand (POD) is currently used in the publishing industry and is being applied to textile printing (Hunting et al., 1995). POD may enable a new cultural and economic movement focused on creation and production instead of consumption (Haugland, 2006). POD publishing allows customers to print single products or small quantities of merchandise rather than a large minimal order of one type of product. Short-run digital printing (SRD) allows print companies to maintain small inventory levels and when combined with the Internet as a distribution and marketing tool allows businesses wider access to potential customers than traditional market means (Haugland, 2006). This mode of production is applicable to the textile world as a way to manage inventory levels and ensure that each piece produced is sold. The textile and apparel industry is lowering inventory levels and reducing the length of time spent from initial product design to market release. By implementing SRD and POD inkjet digital textile printing the textile and apparel industry can achieve these goals (Cahill, 1997).

The POD business model is currently being used by inkjet digital textile printing companies who don't produce something until a customer orders it. Some of these POD inkjet digital printing textile bureaus include First2Print, InkDrop Printing operated by [TC^2] in Cary, NC, Karma Kraft, Spoonflower and SuperSample. Some POD inkjet digital textile print bureaus are aimed towards the higher end of the textile and apparel industry and provide sampling, custom and short run capabilities for industry and others are aimed at the craft and artist market and cater to a range of customers from casual to professional. Several of POD inkjet textile printing companies are based in large cities, such as New York, while others are located in smaller areas, such as the Research Triangle in North Carolina.

The POD manufacturing model applied to the textile and apparel industry reduces the amount of time spent on pre-colored textile purchases and decision and reduces the level of raw material inventory needed to be carried by the manufacturers. Inkjet digital printing of textiles has the capability to replace some of the pre-production color processes beyond that of sampling or prototyping new designs. Inkjet digital textile printing also provides for short-run textile printing (Gregory, 2004), enabling short run printed-on-demand yardage. Customers who utilize this capability can inexpensively create small collections of high quality goods across many subsets of the textile and apparel market (Choi et al, 2003).

Inkjet digital textile printing with pigment-based colorants eliminates the wet post processing required for dye-based printing. This factor combined with the potential for lower material and process costs of pigment printing compared with dye printing places inkjet digital textile printing with pigment-based colorants in the market forefront. POD manufacturing utilizing inkjet digital textile printing grows upon the agile manufacturing process studied by [TC^2] that refers to a form of textile printing and apparel manufacturing process that is integrated for on demand order and fulfillment (Work, 1998). Agile manufacturing requires manufactures to be able to print, cut, sew and ship a product upon demand or order. When agile manufacturing is combined with pigment inkjet textile printing it creates the technological and market opportunity of distributed printing. Distributed printing is a term describing small textile fabrication (in this case printing) facility that receives design and product information electronically then manufactures the product at or near the retail outlet (Work, 1998). This is similar to the POD system used for literature printing and that is currently being applied to inkjet digital textile printing. Distributed printing capabilities of inkjet digital textile printing using pigment-based colorants when combined with digital design, offers potential cost savings, as well as reduced inventory levels and design risk and can drive some parts of the textile printing industry away from screen printing and towards inkjet digital textile printing (Work, 1998).

Current inkjet digital textile printers are engineered with fabric-handling mechanisms and are integrated with color management and raster image processing (RIP) software. Colorants are developed and improved to provide larger color gamuts and fastness. Finishing systems for inkjet digitally printed textiles are available for heatsetting or pigment curing, dye-based colorant steaming and washing, and disperse dye transfer. New inkjet digital textile printers allow for roll-to-roll printing and direct-to-garment printing. These new technologies are usually engineered with smaller footprints than conventional printing systems to accommodate the smaller production runs supported by inkjet digital textile printing as well as to fit a variety of locations (King et al., 2009). Innovations in inkjet digital textile printing will make the technology easier to use by POD textile print bureaus and increase the rate of adoption of inkjet digital textile printing and the POD and SRD business model by the textile and apparel industry.

2.1.2.2. Mass Customization

According to Fralix (2006), "Mass customization has emerged as a practice that combines the best of the craft era with the best of the mass production era" (p. 295). Interest in mass customization has grown since the 1990's and has become a focal point for developing new models of supply chain management, product lifecycle management (PLM) and product development (Fralix, 2006). The term itself today refers to integrating the cost effectiveness of mass production with the agility, consumer empowerment and product variety of customization. Mass customization involves the customer in the product design process (Choy & Loker, 2004). Mass customization provides product customization and variety that satisfies the textile and apparel market's current focus on the individual consumer's needs. This will help to shift the textile and apparel industry away from mass production towards mass customization (Senanayake & Little, 2010).

Ongoing technological advances in the field of PLM for product forecasting, management and design enables mass customization and quick response (Kincade, Regan & Gibson, 2007). Concurrent and compressed operations during the product lifecycle will move the apparel product development and design process closer to the consumer and reduce time-to-market (Kincade et al., 2007). PLM and supply chain management systems are becoming increasing digitized. This allows for a decrease in the number of products ordered and manufactured. Increased technological efficiency results in increased supply chain flexibility and shorter turn-around times. Being able to produce a product run consisting of single-item at a cost able to compete with traditional mass products is becoming a reasonable goal for the textile and apparel industry.

Mass customization is an emergent business and manufacturing strategy for the textile and apparel industry, which allows the customer to participate in the product design process (Choy & Loker, 2004). The predominant manufacturing method for the textile and apparel industry is mass production. One of the main characterizations of mass production is the large material inventory required throughout the manufacturing process from raw materials to finished products. However, the lack of communication and co-operation along the supply chain, as well as the requirement of advanced forward planning and long turnaround times, means that retailers and manufacturers often have to mark down or otherwise dispose of unsold and unsellable merchandise (Fralix, 2006).

Lean manufacturing, quick response and just-in-time manufacturing are strategies that the textile and apparel supply chains have implemented to reduce time-to-market of products while increasing efficiency and productivity (Roberts, 2004). The quick response strategy seeks to create a more collaborative environment between supply chain members and to manage and overview the entirety of a products life spent in the supply chain (Fralix, 2006). One of the driving forces for quick response manufacturing has been changes in consumer purchasing behavior. Purchase frequency has decreased from approximately three months to an average of six weeks between making a purchase (Littlewood, 2006). Consumers expect to see new products available upon each visit to a store and retailers must comply or risk losing sales. Littlewood (2006) states that the change in consumers' purchasing frequency led to today's fast fashion and increase in the number of seasons or new product releases. By managing the supply chain and increasing communications between members the hope was to decrease the amount of time materials and products spent in the manufacturing and finishing process and to shorten the time needed between ordering merchandise and receiving it to be sold. This would aid retailers and manufacturers in ordering what their customers were more likely to purchase and reduce the level of merchandise marked down at the end of season. Mass customization is one approach to supply chain management for the apparel industry in developed countries, such as America, to remain competitive over less developed countries (Senanyake & Little, 2010).

Companies that engage in mass customization are able to capture market share and gain an edge over the competition (Fralix, 2006). Textile and apparel companies engaging in mass customization are able to accept input from their customers concerning product design and are able to get the finished product to the customer in a short time and at a competitive price. Products can be customized by the consumer to specifications, such as fit and design aspects (Senanayake & Little, 2010). Inkjet digital textile printing technologies are directly applicable to mass customization of textile and apparel products due to the reduction in the number of steps needed in printing. The increase in application and use of digital printing of textiles positively impacts the current and future state of mass customization (Tyler, 2005). Innovations in technology, such as inkjet digital textile printing, can enable mass customization capabilities with the efficiencies of mass production methods (Ulrich, Anderson-Connell & Wu, 2003). Inkjet digital textile printing is being embraced by textile printers to gain a competitive edge through offering small batches, one-off designs, agile manufacturing and mass customization (Byrne, 2004). By implementing digital printing technology manufacturers will be able to react quickly to trends and changes in color and print designs. Due to the digitalization of the design and production of textile prints an inkjet digital textile printer can print large or small orders without there being a difference in costs other than that of the raw materials used. For example a company can print 1000 yards of one print design or 1000 one yard prints without losing time or incurring additional costs to set up screens or rollers for a different print (Fralix, 2006).

A prime example of cost effectiveness in using inkjet digitally printed textiles and mass customization is when the fiber content of the substrate being printed is expensive. One such fiber is silk, which is usually printed in short-run lengths even with conventional printing methods, and as such is a prime target for costs savings by incorporating or switching to inkjet digital printing technology (Provost, 2009). Inkjet digital textile printing has often been compared to conventional printing however TC^2 found that after studying and monitoring inkjet digital textile printing systems for 10 years that an increasing number of production-oriented systems have been introduced to the inkjet digital textile printing market (King et al., 2009). Newer production-oriented inkjet digital textile printing systems will enable wider adoption of mass customization in the textile and apparel industry. Mass customization integrated with inkjet digital textile printing will continue to change the textile apparel industry's concepts about product lifecycles and manufacturing methods.

2.1.2.3. Engineered Designs

Engineered designs usually refer to textile prints where the print design is created with the final product in mind or are textile designs that "follow, or decide, the form of the garment (Nicoll, 2006 pp. 25)". According to Parrillo-Chapman (2008), engineered designs can be used for aesthetic reasons to, "hide seams, accentuate shape or movement, divert attention from an area of the body, or continue a motif or pattern across a seam, dart or closure (pp.2)." Pattern pieces can be filled in the desired print and printed out on an inkjet textile printer. Engineered designs offer tailor-made customized products while prints can be scaled and placed to accentuate or downplay the wearer's figure (Jennings, 2007). Textile designs are able to be printed without repeat size or color limitations (May-Plumlee & Bae, 2005). Inkjet digital textile printing's engineered print capabilities make it possible to print out a variety of different designs, colors and prints on a continuous roll of fabric without a need to change screens or cleaning. TC^2 in Cary, NC, was one of the progenitors of engineered printing with inkjet textile printers. Early models for engineered designs focused on matching prints over seams using an Adobe Photoshop plug-in to manipulate the print design around the digitized apparel pattern dart for a seamless appearance when printed and sewn (King, et al., 2009). CAD systems, such as Adobe Photoshop, as well as apparel pattern generation software and textile print software opens an opportunity for an easily created and manipulated engineered design.

Engineered designs printed using an inkjet digital textile printer allows for improved aesthetics of print design and placement and reduced waste. Textile print designs can be filled in to customized pattern pieces. These pieces are the only elements printed and upon post-treatment can simply be cut out and sewn together (Parsons & Campbell, 2004). Figure 6 (Parsons & Campbell, 2004) demonstrates an engineered design marker layout for inkjet digital textile printing that is ready to be cut and sewn after fixing the colorant. Engineered designs such as Parsons & Campbell (2004) in Figures 6 and 7 demonstrate the digital manipulation of pattern pieces and the integration of photo-realistic prints into an inkjet digitally printed garment.

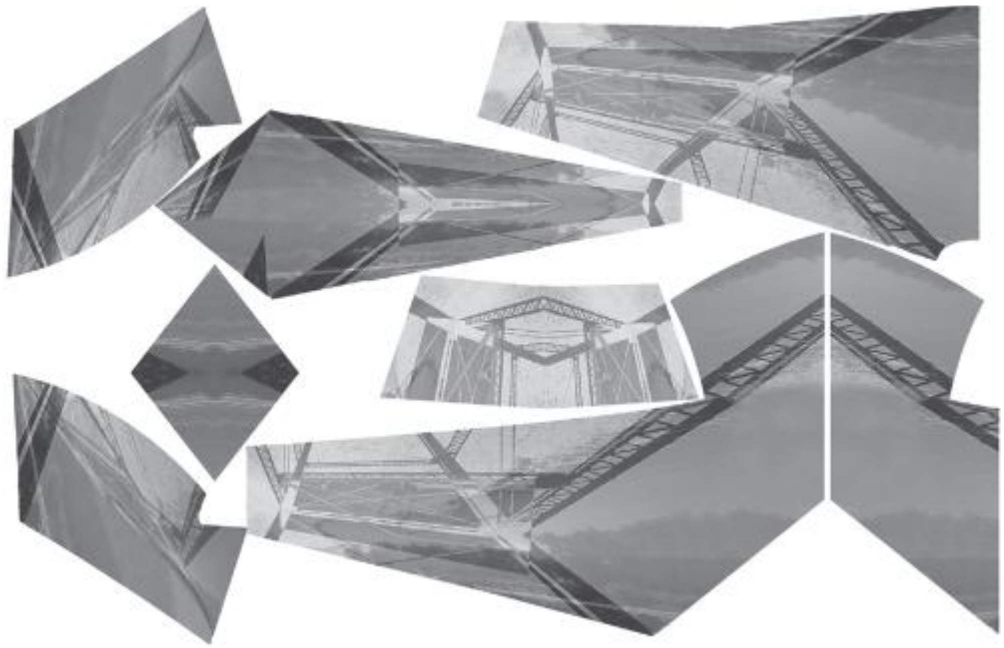


***Figure 6*: Marker layout used for printing right half of "Silk Bridge" engineered print design jacket (Parsons & Campbell, 2004)**

Figure 7 (Parsons & Campbell, 2004) shows the final sewn engineered design. Note the placement and integration of colors and print placement that emphasizes the sleeves and cuffs.

***Figure 7*: Completed "Silk Bridge" engineered print design jacket (Parsons & Campbell, 2004)**

Engineered print design used in conjunction with mass customization and just in time production can reduce material waste (May-Plumlee & Bae, 2005). As inkjet digital textile printing utilizes less water and colorant than conventional textile printing those wastes are reduced, when combined with engineered print design fabric wastes are reduced as well. Mass customization and just in time production such as POD inkjet digital textile printing reduces the chance of unsold products and negates the need for conventional inventory levels and warehouses. A textile and apparel production system utilizing inkjet digital textile printing with engineered print design and a mass customization and/or POD business model will save on overhead costs and material waste. Engineered designs printed with inkjet digital textile printers provide more efficient and sustainable use of raw materials, such as fabric, colorants and water, especially when using pigment-based colorants (King et al., 2009). One impediment to digitally printed engineered designs is controlling for fabric bow, skew, and dimensional change after fabric finishing. Tests for fabric dimensional change pre- and post-finish must be done and changes to the apparel pattern and textile print placement must be done prior to printing (King et al., 2009). Figure 8 is an example from Mimaki, a current distributor of inkjet digital textile printers, demonstrating both the photo-realistic capabilities of the technology and an engineered pattern placement. Note the original drawing in the lower left corner.

***Figure 8*: Photo-realistic engineered print design by Mimaki**

(http://www.mimaki.co.jp/english/tx/example/sample.php)

2.1.2.4. Surface Effects

Due to the photo-realistic capabilities of inkjet digital textile printing unique and fashion forward surface effects are able to be achieved. When designers have thousands of colors at their disposal, they are able to create unhindered and push the boundaries of textile designs. Traditional surface effects that are achievable with screen printing such as trompe l'oeil are easily reproduced with inkjet printing. Fabrication and embellishment techniques such as cross-stitch embroidery, sequins, gingham, stripes and plaids can be simulated using a CAD software system such as Photoshop or Illustrator and printed onto the desired fabric (Bowles & Isaac, 2009). Inkjet digital textile printing's ability for photo-realistic prints has inspired designers seeking to exploit photography's potential to create textile designs.

Designers are able to explore how distance and scale is perceived and photographic functions such as format and focus can be integrated into textile and apparel surface design (Treadaway, 2004b). Artists, such as Amy C. Clarke, who work in beading and/or embroidery, are able to photograph an image, manipulate the image in a CAD software system such as Photoshop, and then inkjet digitally print the final image as a guide for sewing beads or embroidering onto the fabric (Treadaway, 2004b). The ability to recreate original artwork and photographs appeals to niche markets such as artists and designers seeking to produce textile products with printed photographs, painted effects and textures and museums looking for products to sell based on their collections (Eckman, 2004). High end fashion designers, as well as textile artists, have embraced the capability of inkjet digital textile printing to simulate unique and photo-realistic textile prints as will be discussed further in section 2.1.4.

2.1.3. Limitations

The inkjet digital textile printing has many capabilities and advantages for the textile and apparel market and industry, but there are limitations. CAD and CAM technologies have been integrated into the textile and apparel product development lifecycle, but the constant stream of technological advances requires training and expensive updates to technology and software. Inkjet digital textile printing technology has high equipment and materials costs and substantial initial investments and printing speeds and capabilities must improve in order for production level textile printing to be done with inkjet printers (Byrne, 2004). Some of the limitations preventing inkjet digital textile printing for production include their lower speed and reliability compared to conventional printing technology (Dehghani et al., 2004). This section will examine limitations of the technology and the high learning curve required for use of inkjet digital textile printing.

2.1.3.1. Technology

Perhaps the largest impediment to mass acceptance of inkjet printing of textiles is the technology itself. Colorant type and color range is still a limitation in spite of recent advances. As inkjet printers are based around a CMYK process color system rather than spot color system used for conventional textile printing testing and matching colors can be difficult (Ross, 2001). Colorant types must be compatible with current inkjet printhead technology therefore glitter colorants, flocking and devore techniques are unavailable (Nicoll, 2006). Availability of pre-treated fabric for acid and reactive dye-based colorants is still somewhat limited unless the printer operator is willing to pre-treat the fabric themselves.

Printing speeds of inkjet textile printers currently are around the 30 m^2/h range whereas speeds over 200 m^2/h will be needed to replace conventional screen printing in the current market (Kobayashi, 2006). However, newer models of digital textile printing systems have improved the printing speeds to 70m^2/hr and even 150-190 m^2/hr (King, 2009; Caccia & Nespeca, 2006). A recently introduced inkjet digital textile printer titled LaRio, created by MS Macchine, can achieve printing speeds of up to 70 m/minute or 4200 m/hr (King, 2011). Costs associated with the technology need to be lower to increase the competitiveness and acceptance rate of digital inkjet textile printing in the market.

One of the limitations for utilizing inkjet textile printing technology for product sampling is how easily and accurately reproducible such samples are. This can depend on a variety of circumstances such as variations in the substrate and preparation, the ink and printhead quality and consistency, as well as the performance reliability of the inkjet printheads (Dawson, 2001). While inkjet digital textile printing usually prints without color separation many CAD/CAM systems can create color separation files from a color reduced graphic file to move to conventional textile printing (Mikuz, Sostar-Turk & Pogacar, 2005). Colorants used for inkjet digital textile printing and conventional printing differ in printed appearance, inkjet prints appearing granular and pixel-like whereas conventional textile printing colorants have uniform coverage. However, printed designs are usually visually comparable between an inkjet digitally printed textile and a conventionally rotary screen printed textile, especially for darker colors where more ink drops are applied for increased coverage (Mikuz et al., 2005). Physical differences between prints from industrial rotary screen printers and inkjet digital textile printers are the lack of overlap of color areas, usually around 1mm for conventional printing. This is due to the physical overlap between colors in conventional textile screen printing not being necessary in an inkjet digital textile printer, which prints all colors simultaneously instead of one at a time (Mikuz et al., 2005). The difference in colorant and printing techniques in inkjet digital textile sampling and conventional textile production printing complicates color matching and reproduction issues (Henry, 2004). When using inkjet digital textile printing for sampling, both the inkjet printhead resolution and fabric structure should be taken into account in order for the sample to be reproducible with conventional printing. While both inkjet digital textile prints and conventional rotary screen prints are colorfast to washing, inkjet digital textile prints are less colorfast to artificial light and wet rubbing or crocking (Mikuz et al., 2005). Inkjet digital textile printing technology has improved greatly since its introduction to market but there are still limitations to its expanded acceptance and ease of use.

2.1.3.2. Learning Curve

Users of inkjet digital textile printing technology face a learning curve in utilizing the technology to the full potential. Whether sampling textile products or manufacturing print on demand products users and customers of inkjet digitally printed textiles must re-evaluate the design and manufacture process. Utilizing digital technology for design and product development requires aesthetic knowledge and skill, as well as knowledge of tools such as software and hardware systems (Treadaway, 2004a). The machinery and hardware system of an inkjet digital textile printer is different than conventional textile printers and the design process and software systems used are either new or utilize different functions. The product development process for inkjet digital textile printing differs from conventional printed textiles. This includes color management and colorant formulation. Although conventional textile printing has simplified technology used for product development over many years the technological demands placed on inkjet digital textile printers are still very high (Tyler, 2005). Those who choose to use inkjet digital printing technology must educate themselves about the process in its entirety. This can often cover not only the mechanics of the inkjet printer but also colorants, substrates and textile properties and computer software systems. By understanding and re-educating themselves about the entire inkjet digital printing process they can create an integrated and coherent product development and color management strategy (Tyler, 2005).

Nicoll (2006) states that, "New professional and craft roles are being defined. More and more unique creative skills are being transferred onto this new technology" (p. 24-25). As well as requiring adopters of this technology to re-educate and train their employees on how to use and incorporate inkjet digital textile printing into their product design process new fields and job opportunities are being created. Inkjet digital textile printing requires an integration of many aspects and skills ranging from computer aided design to digital and physical color management skills as well as knowledge of dye chemistry and textile properties. Current and future users of this technology will be required to be knowledgeable of printing and software technology and be creative and color savvy.

One issue faced by people using inkjet digital textile printers is in controlling color and management of color profiles. True 'black' in textiles is difficult to attain throughout the textile industry and is particularly difficult with inkjet digital textile printing. Acid and reactive dye-based colorants have difficult times creating true black and depending on the absorptive and/or textural qualities of the textile substrate black colorant will be dispersed through the textile and appear more grey than black (J.R. Campbell, 2006). Users must also be familiar and competent with instrumental calibration of printers and monitors and the company must be able to support the continued printer downtime and textile and colorant used for calibrations. Companies and printer operators must also be made aware of the need for repeated calibrations of the same printers due to changes in textile quality (J.R. Campbell, 2006). Companies either currently using or seeking to use inkjet digital textile printing must be willing to search for qualified employees or able to invest in training employees in the multiple aspects of the technology, such as CAD software and computer technology, color and textile choices and behaviors, as well as the maintenance and use of the inkjet printers (J.R. Campbell, 2006).

Knowledge of textile and fiber characteristics is one of the most significant limitations and barriers for implementing mass customization and/or engineered designs with inkjet digital textile printing. Textiles often stretch during printing and can be distorted by the feeding mechanism of the printer. Wet post-processes, such as steaming and washing, can further distort printed textiles, causing bowing, skewing and shrinking (May-Plumlee & Bae, 2005). Designers and print operators face not only the technological learning curve, but a learning curve of textile behavior and qualities as they pertain to print quality and the quality of the finished engineered printed product (King et al., 2009).

Limitations of inkjet digital textile printing pertain to the technology and its use. The knowledge and skill level of the users can be considered a barrier to the wider use and acceptance of inkjet digital textile printing. While the technological aspects can be improved through research and advancements, the learning curve of users requires time and monetary investment in training and education of users and designers.

2.1.4. Demand

Demand for inkjet digital textile printing is being driven in America by entrepreneurs and niche markets, as well as the resurgence in craft products. Niche markets such as inkjet digitally printed textiles provide a way for American companies to remain competitive in today's international textile industry (Parrish, Cassill & Oxenham, 2006a). The short-run and POD capabilities of inkjet digital textile printing make it a prime manufacturing method for products and services that cater to the niche markets that exist, not only in the American textile market, but internationally as well. Crafting's market niche is evident through its presence on the Internet. Crafters can sell, shop and disperse information about crafts through websites, such as the web-based craft marketplace Etsy (www.etsy.com), and other textile craft oriented websites, such as Craftzine (www.craftzine.com), and blogs, such as Craftster (www.crafster.org). Virtual quilting circles communicate via on-line bulletin boards and Internet clubs (Johnson & Hawley, 2004). Crafters today can design and print their own textiles through CAD software systems and inkjet digital textile printing bureaus and can sell their products over the Internet from their home. Technology and the ingenuity of entrepreneurs are revitalizing the small business model and cottage industry of the textile market.

2.1.4.1. Niche Markets, Small Businesses & Entrepreneurs

A mature industry such as the American textile and apparel industry can improve competitiveness through specialization and niche marketing (Parris, Cassill & Oxenham, 2006b). The textile and apparel industry has traditionally been used by developing countries due to its historic economic success and its labor-heavy and capital-light business model (Parrish, Cassill & Oxenham, 2004). Technology, such as inkjet digital textile printing offers advantages to textile printing companies in America against competition from lower cost countries (Gregory, 2004). Due to the proportion of the textile and apparel industry that relies on manual labor, America has many of its manufacturing facilities located off-seas. One proposed way for the textile and apparel industry to stay vibrant and economically healthy in America is by focusing on technological based enterprises. The textile and apparel industry can remain competitive against lower priced imports by specializing in innovation, quality and technology driven niche markets (Parrish et al., 2006b). Niche market textile and apparel companies in America are able to provide more innovative and technologically advanced products, along with quick response times and mass customization capabilities (Parrish et al., 2006a). Developed countries, such as America, which have high wages and seek low unemployment numbers, must look at new ways of doing business to compete with other countries that can pay workers lower wages. Many developed countries are therefore moving away from labor intensive activities into more capital and knowledge-based activities (Parrish et al, 2004). Small businesses and entrepreneurs are drivers of the new knowledge-based market due to their willingness to develop and try out novel ideas and products (Gelderen, 2008).

According to Kotler (2003) a niche market has the following characteristics; customers have distinct needs, customers will pay a premium price to meet their needs, the niche is unlikely to attract competitors, the company will gain certain economies through specialization and the niche market segment has potential for growth. According to a study by Parrish et al., (2006a) niche markets are characterized by a loyal customer base, a specialized segment of the market (going beyond market segmentation), a higher price point and a unique product. Catering to a niche market gives a company a competitive advantage in customer satisfaction and service. Because a niche market is relatively much smaller than a mass market, it is necessary for the company to constantly perform market research about their customer(s) and gets to know them and their specific demands very well. By having such an extensive and in-depth knowledge of the customer, the company is better able to provide the level of customer service and variety and assortment of products the customer requires. This in turn creates customer loyalty, return sales and gives the company a positive reputation, which allows for word of mouth and other types of viral (and free or low-cost) marketing (Parrish et al., 2004). Small business owners/managers consider customer service, communications and relationships an important factor for success (Blankson, Motwani & Levenburg, 2006).

Small companies have an advantage over larger companies when serving fragmented or niche markets. Small or niche businesses benefit from usually being local; they tend to have better knowledge of local networks and contacts, a local image and reputation and usually offer a more personal customer service experience (Kean, 1996). However, small businesses tend to be unequally matched when it comes to marketing skills, business knowledge and financial and other miscellaneous resources (Fillis, 1993). Actions such as marketing and public relations are handled by the company itself instead of being allocated to an external third partner. Due to their small size these entrepreneurs and business owners are often overlooked by the press and must communicate their brand, reputation and identity through other informal and more novel methods usually led by the owner/manager. An owner/manager of a small business who is more willing to take risks and has a more entrepreneurial outlook can use networking with other smaller businesses and networks, as well as working within their company to quickly gain a public reputation, even if only in its specific niche market (Fillis, 1993). Small businesses are able to operate from a variety of areas, not necessarily a physical storefront or office.

Home-based businesses and workers are small independent businesses where the employee(s) perform some or their entire job at home or run their own business from home. There are many reasons for people to work from home, but the main reasons are flexibility of work hours and schedules, personal pride and sense of accomplishment, and fewer distractions. Textile artists who work or run their own business from home are more able to offer customized products and services to a small niche market (Soldressen, 1998). For home-based businesses, especially those that are geared toward the arts and crafts sector, economic success is second to creative success. Textile artists who are able to support themselves with their home-based businesses do not consider success solely as economic independence largely because they take pleasure from their work (Soldressen, 1998).

A small business can use the Internet for supply chain management and sourcing, processing and sending orders, sending and receiving sensitive documents and processing prompt and accurate payments. By opening up the possibilities of supply chain management and product life-cycle management to small entrepreneurs the Internet empowers and aids the entrepreneur, as well as the entrepreneur's customers and sourcing partners (Yrle, Hartman & Walsh, 2004). Internet-based businesses offer entrepreneurs and small business owners increased flexibility of operation compared to traditional brick and mortar businesses. Start-up costs associated with internet businesses are much lower than traditional businesses making business ownership more available to those who may be unable to procure enough capital to open their own businesses (Yrle et al., 2004). The anonymity that the Internet provides means that those who may be subject to discrimination in the physical world are less likely to be discriminated against in both business and social aspects (Jome, Donahue & Siegel, 2006).

Home-based Internet businesses are characterized by many qualities, according to Gelderen (2008), the first characterization is speed. As most correspondence and payments take place instantly with e-mail and payment systems, such as PayPal, the turn-around and processing times it usually takes for an order is dictated by the speed of the person's internet connection and how often they check their e-mail. The second characterization of home bases internet businesses is that many owners/operators have multiple incomes from a second job, either full or part-time or another self-owned business. What makes internet-run home businesses attractive and accessible to entrepreneurs is the low cost of set up and operations. The third characterization is the inexpensive cost of entry and operation due to low costs of internet access and web hosting. A business owner can operate their business using only e-mail and a cell phone with as much communication done through the internet. The fourth characteristic is that home based internet businesses are very lean and small. Instead of an office, the business can be run from a laptop or even a smart phone from anywhere. Many businesses keep a small number of employees other than themselves to keep the business manageable and keep other aspects of the business small. The final characterization of home based internet businesses is working smart. By allocating time and resources to where they'll be able to do the most good for the business, the owners can maximize the possible financial gains. An example of working smart is the use of free and cheap marketing over the Internet. By utilizing social and cyber-networking models businesses are able to build free word of mouth advertising and build their brand with minimum of economic output (Gelderen, 2008). These aspects of home-based Internet business make it an attractive business model to entrepreneurs.

Not only are small businesses and entrepreneurs utilizing the Internet to market to niche markets, they are also focusing on geographically local niche markets and products. The Industrial Revolution saw an influx of rural workers moving into cities seeking jobs at new factories (Shanklin, 1999). States and cities specialized in whichever manufacturing or other business they had an advantage in, either due to natural resources and their location or due to the business intelligence and power of its citizens. Currently, America is experiencing anther revolution geared by technology and globalization (Shanklin, 1999). Communities may decide to engage in or promote entrepreneurial enterprises to strengthen or grow its business and economic resources. To be successful in starting and/or growing their local businesses and markets it is vital for the community to identify what type of business it is best suited for. Citizens must weigh their economic resources, geographic location, demographics of its citizens, technical education, transportation and infrastructure and even climate. Organization and communication between the community, government and other business establishments is important to create a cohesive and beneficial business and economic strategy. Coordination of programs and agencies will help link entrepreneurs and businesses to the citizens thereby empowering communities to grow their economic strength (Shanklin, 1999). Starting a small business or entrepreneurial business is relatively easy in today's market environment. One can start a small home-based business selling products through the Internet. This allows for marketing and selling to niche markets and open a large variety of niche products to consumers, such as handmade textile crafts.

2.1.4.2. American Craft Market

The modern renewal of handicrafts in America can be traced back to the Arts and Crafts Movement started by William Morris in England during the nineteenth century. The concept of combining aesthetic ideals with well-made artisan products was in reaction to industrialization. Morris believed that the machine-made products were ugly and of poor quality, and that industrialization de-humanized workers and removed their sense of pride and joy in creation (Christen, 2008). One aspect of the Arts and Crafts Movement was geared towards an aesthetic ideal of natural beauty combined with well made products. Morris felt that every day products should be beautiful and useful to bring beauty into everyday life and drew inspiration from medieval aesthetics and the Romantic revivals of the period (Harvey & Press, 1996). A second aspect of the Arts and Crafts Movement was geared towards social and economic reform. Morris sought to redress the production and labor wastes and misuse associated with the capitalist industrialized manufacturing of the day, preceding current attention to sustainability in textile and apparel consumer goods (Miller, 2011). By seeking to return to a handcrafted and artisanal production method Morris hoped to bring back a sense of joy, dignity and personal satisfaction to workers. The Arts and Crafts Movement sought to combine the idea of craftsmanship with aesthetic ideals to create beautiful and functional items. Morris strived towards social and economic change through craft production to return to guilds and create co-operative businesses and unions (Christen, 2008).

America embraced Morris's aesthetic ideals and the Arts and Crafts Movement's appreciation for handcrafted items but never fully embraced his desire for social and economic change. The Arts and Crafts Movement remained a solely aesthetic one restricted to the upper and middle classes due to the prohibitive costs of handcrafted items. Some supporters of the movement, such as Julia Hoffman of the Arts and Crafts Society of Portland, did attempt to teach people in the lower-class handicrafts and saw it as a way to empower them to earn extra money and beautify their own houses. Hoffman and others who saw handicrafts as a home business opportunity for the lower-class did not take into account the long working hours of the working class or the relatively high costs of raw materials (Christen, 2008). Other social reformers saw the return to craft production and the revival of a cottage industry as an antithesis to the sweatshops and factories of the time (Boris, 1989). The aesthetic ideals and high value of handcrafted items remained in America's psyche and has re-emerged at various times under different guises since the inception of the Arts and

Crafts Movement. Indeed, handicrafts were viewed by some during the Great Depression as a solution to the rampant unemployment, particularly in rural areas (Boris, 1989).

Today the phrase craft is often used interchangeable with handicraft, arts and crafts, Do-it-Yourself, DIY, handmade, artisan and many others. For the purpose of this research the terms handicrafts and crafts are denoting traditionally handmade/sewn textile products ranging from apparel, textiles, and accessories. The term craft or handcrafted can usually mean to be referring a product that has been made with a high proportion of handmade or human input as opposed to machine produced and with great attention to materials, workmanship and design (Fillis, 2004; Kean, Niemeyer & Miller, 1996). In today's post-industrial market, the craftsperson must compete with simulated craft products that are mass-produced using industrial and technological manufacturing techniques (Fillis, 2004). In the arts and crafts market, small businesses face difficulties concerning available resources, as well as opposing business views by arts and crafts producers who either create art for art's sake or art for business's sake. Due to the small budgets many arts and crafts small businesses must work with, many depend on cheaper and/or free publicity, such as word of mouth referrals, to build their business (Fillis, 1993).

The current craft market in America combines a Do-It-Yourself (DIY) attitude with an appreciation of independent, small and local crafters, designers and artists. In the Appalachia's, crafts provide the region with a method for keeping traditions alive and providing economic security. Entrepreneurial pursuits help crafters have economic and creative independence while reinforcing and sustaining their cultural identity and craft traditions. This "Artisan Enterprise" creates a viable alternative market place and allows individuals to prosper from doing what they love (Paige & Littrell, 2002). Currently the American craft market appears to be a fragmented marketplace, broken up into smaller regions and types of crafts while the level of expertise, quality and prices vary. Due to the fragmented and diverse nature of the modern craft market, networking, either face-to-face or virtually through the Internet, is vital in place of traditional marketing (Paige & Littrell, 2002). In fragmented industries and markets, small firms have an advantage over large firms when it comes to local image, contact and personal service (Porter, 1980). Communication and networking between crafters and small arts and crafts businesses creates a sense of community, even if it is a virtual one spread over wide geographic distances. The website Etsy functions as such a community; it is an Internet-based marketplace for sellers and buyers to come together, gather information and network. Crafting is often done predominantly for personal enjoyment and to keep craft traditions alive; economic success is not the only measure of success and is tied to the crafters/artisan's sense of personal fulfillment and sense of creative freedom (Paige & Littrell, 2002). Creative idealism often clashes with commercialism in the craft market and recognition and reputation for the creator, rather than selling the creation is common (Fillis, 2003).

Because crafts are a niche and specialized product, they differ greatly from mass-produced goods in terms of product life-span and profit margins. To control costs and increase sales of craft products sales people must be educated and trained about the product to communicate to the consumer the cultural value of the product. The production, marketing and retailing life-cycle of handcrafted items is usually marked as a product at least partially made of natural materials with minimum technological interference and which is marketed and distributed by the craftsperson (Kean et al., 1996). A survey of craft retail stores owner/managers demonstrates that many believe crafts should be produced not for economic gain or marketability but as a creative form of self-expression along with other art or designer products (Fillis, 2004). The ability to follow and build a business by being able to express one's uniqueness and creativity allows crafters a sense of pride and control in their own business that overshadows successes such as large profits and/or expansion (Fillis, 2004). While the American craft market is small and segmented, it does support the local economy wherever there are crafters selling their wares. One roadblock the craft market faces is the fact that many crafters who also sell their products may identify themselves as more an artist or designer instead of a business person (Kean et al., 1996).

Crafters and craft retailers can be placed into four types of mindsets, according to Fillis (2004). The 'Lifestyler' works with handicrafts because of a perceived quality of life and may be unwilling to grow their business past a point where it ceases being enjoyable. Lifestylers value the creative and market freedom of the craft market. The 'Entrepreneur' takes a more traditional business route to the craft market and realizes the opportunities available if they are willing to take risks with their business and grow and develop their customer and target market base. Entrepreneurs view craft products as commercial products that allow them to run and operate their own business. A third type, the 'Idealist' views the craft product as a creative art piece and may approach the business aspect of selling their pieces uncompromisingly and may not take note of customer's wants or needs. The final type of crafter and craft retailer is the 'Late Developer' who enters the craft field after working in unrelated fields but has decided to make a career change for a different/better lifestyle (Fillis, 2004). These four types of crafters and craft retailers were used to develop the four user types, crafter, artist/artisan, designer, or small business owner/entrepreneur that respondents were asked to identify themselves as in the survey instrument used for this research.

The view of craft and culture's relation to one another in the 19^{th} and early 20^{th} century was a romantic and idealistic one that viewed factory driven production methods as dehumanizing and alienating. Handicrafts were viewed as ennobling and an expression of humanity. Due to this romanticizing of hand work, craft activity has been viewed as a way to empower individual workers while prevailing against the mass production and factories. Although this view can be seen as trying to work against time and turn back Industrialism, crafters and artisans have long been balanced between human power and machine power (C. Campbell, 2005). This dichotomy between the human/ hand-made item and machine driven mass production is still seen today. Consumers who actively choose to purchase handmade craft items could be said to be seeking to reconcile the romantic and humanizing view of handcrafted products versus the alienating, mass produced products available in the market today. A crafter in today's market is someone who may not necessarily make an item from scratch but is someone who is an individual artisan or craftsperson who designs the product, selects the materials and who makes or supervises the making of the craft object (C. Campbell, 2005). Handcrafted items today usually are products that have at some point in the product lifecycle been touched by both machinery and the human hand. The appeal of crafting and craft products can be seen as a reaction to the increase in mass consumption and a way for individuals to assert their creativity, authenticity and choice in a retail market overshadowed by large corporations powered by solely economic interests (C. Campbell, 2005). The term craft in terms of craftsmanship and skill has changed through the years from viewing handcrafted objects having a practical consistency in quality to containing irregularities and imperfections to prove that the object is indeed hand and not machine made (Betjemann, 2008). When mass production of textile prints was introduced, technically perfect fabric prints were the most desirable, but this changed in the late twentieth century with a consumer backlash against the technological and mechanization of textile prints (Carlisle, 2001). Textile manufacturers now can incorporate deliberate faults into the textile prints to simulate a hand-crafted look and provide unique and customized products (Carlisle, 2001). Inkjet digitally textile printing's capability to printing photo-realistic prints will allow crafters and designers to either scan in or photograph their hand-created objects and print with minimal technological interference their drawings, painting, sculptures, photographs or other designs/art.

2.1.4.3. Fashion Design

Recent years have seen high-end fashion designers using inkjet digital textile printing in their collections. The unique capability of inkjet digital textile printing to integrate CAD and graphics software, digital photography and even video and other special effects has captured the imagination of fashion designers (Bowles & Isaac, 2009). Figure 9 is an example from Mary Katrantzou's Spring/Summer 2010 collection demonstrating her use of the wide variety of colors along with an unlimited repeat size and print placement offered by inkjet digital printing technology.

***Figure 9*: Inkjet digitally printed dress from Mary Katrantzou S/S 2010 (from www.style.com)**

Figure 10 is a dress from Alexander McQueen's Spring/Summer 2010 collection demonstrating the photo-realistic capabilities of inkjet digital textile printing and an engineered design and print placement.

***Figure 10*: Inkjet digitally printed dress from Alexander McQueen S/S 2010 (from www.Style.com)**

Fashion designers utilize inkjet digital printing for sampling and creating runway designs. Michael Angel is a fashion designer who has worked with First2Print for several years to create runway and retail designs. This has allowed him to offer unique and colorful art-inspired designs and the entire creation process, from sketching through to final product only takes around three weeks (Locastro, 2010). Figure 11 demonstrates inkjet digitally printed designs from his Spring/Summer 2008 runway show.

Figure 11: **Inkjet digitally printed dresses from Michael Angel S/S 2008 Printed by First2Print (from http://www.michaelangel.net/world.htm)**

As a new generation of fashion and textile designers emerge into the market equipped with CAD software and inkjet digital textile printing knowledge, the fashion design market will continue to see unique, innovative and novel textile and apparel designs.

2.1.5. Summary

The literature review revealed that there are designers pushing textile and apparel design boundaries and are capitalizing on inkjet digital textile printing's capabilities. Inkjet digital textile printing is changing how designers approach textile design and is changing the product development process in the textile and apparel industry. The literature review demonstrated that American entrepreneurs, small business owners and crafters are in a position to adopt inkjet digital textile printing as a textile and manufacturing method and business model. Inkjet digital textile printing's capability for innovation is changing the way that textile and apparel designers develop and sample their products. Throughout the supply chain for textiles and apparel new approaches to and ideas about managing inventory levels, production turn-around time and locations of sampling and production. By empowering local and small businesses and entrepreneurs, such as crafters, inkjet digital textile printing is changing the way that people approach designing and purchasing textile products. The capabilities of inkjet digital textile printing including printing in thousands of colors and photo-realistic prints along with removing the necessity of repeating patterns will impact not only the current users of this technology but the students and future users of this technology who will continue to innovate and stretch the boundaries of textile and apparel design.

CHAPTER 3: METHODOLOGY

3. Methodology

To measure and gauge current market demand from niche market users of inkjet digitally printed textiles it was necessary to find a company willing to allow the primary investigator to voluntarily survey their customers. A quantitative survey instrument was designed and distributed to answer the research question and objectives. The quantitative survey instrument was administered via the Internet through a secure, third party survey website called SurveyMonkey. The participating company is a POD inkjet digital textile print bureau that allowed the primary investigator to distribute the link to the survey instrument through the company's weekly e-mailed newsletter. Descriptive statistics and ANOVA were used to analyze the data after respondents were allowed two weeks to reply.

3.1. Research Question

The research question for this research is:

1. What is the current state of print-on-demand inkjet digital textile printing capabilities and limitations as perceived by niche market users?

3.2. Research Objectives

Two research objectives were developed to measure the capabilities and limitations of print-on-demand inkjet digitally printed textiles as perceived by niche market users. The two research objectives are:

1. To determine the capabilities and limitations of different aspects of print-on-demand inkjet digitally printed textiles as measured by the opinions of a group of niche market users. The aspects measured were:

    k. Color Control

    l. Time Needed for Designing

    m. Turn-Around Time for Order

    n. Fabric Choices

    o. Quality of Print

    p. Quality of Fabric

    q. Printable Fabric Width

r. User Skill Level: CAD Software

s. User Skill Level: Color Control

t. User Skill Level: Creating Repeat Patterns

2. To determine if there is a difference in perceived capabilities and limitations of print-on-demand inkjet digitally printed textiles per self-identified niche market user types.

e. Crafters

f. Designers

g. Artist/Artisan

h. Small Business Owners/Entrepreneurs

3.3. Survey of Current Users

A survey instrument was developed to determine the current capabilities and limitations found by the users of the POD inkjet digitally printed textiles. The principal investigator determined that gathering primary quantitative data would be the most time and cost effective method of research as it is a research method suited for finding and describing means, frequencies and other trends in the data (Gaiser & Schreiner, 2009). Standardized questionnaire type surveys such as the survey instrument developed for this research facilitate generalization of findings to the larger population (Babbie, 2007). The survey instrument was composed of quantitative questions and a few open-ended questions. The majority of questions in the survey instrument were Likert scales, asking the survey participants to self-assess their skill levels and to rank their perception of the capabilities and limitations of inkjet digitally printed textiles and technologies. Scaled questionnaires have been utilized to survey those in the craft market (Kean et al., 1996). The purpose of the survey instrument was to determine the conditions of the inkjet digitally printed textile market ascertained from customers of a POD inkjet digital textile printing bureau.

The survey instrument was created and administered through the online survey service www.Surveymonkey.com. Online distribution and gathering methods for surveys are usually more cost effective and have higher return rates than traditional mailed surveys (Gaiser & Schreiner, 2009). To prevent the participating POD inkjet digital textile print bureau from breaking their terms of service with their customers the link to the survey instrument was distributed to recipients of the participating company's e-mailed newsletter. The owners of the POD inkjet digital textile print bureau were allowed to look over the survey instrument for final approval. As an incentive to participate in the study, customers who completed the survey were entered into a raffle to receive fabric printed for free by the participating POD inkjet digital textile print bureau. Multiple steps were taken to guarantee that the users participating in the survey were anonymous and that their personal information was not accessible at any time. Participants are identified below as one of four niche market user types; Crafters, Designers, Artists/Artisans or Small Business Owners/Entrepreneurs. Participants were asked to select which niche market user type they self-identified with the most.

The methodology used in this research was based on the concept of 'Marketing Situation Analysis' as described by Hair, Wolfinbarger, Ortinau, & Bush (2008). Comprised of market analysis, market segmentation and competition analysis this method seeks to identify and assess new market opportunities, identify similar groups of customers based on their characteristics, and lastly to identify strengths and weaknesses of the market and competitors (Hair et al., 2008). For the purposes of this study market analysis and opportunities identification was used, which was comprised of the literature review. Competition analysis was used with a change of focus to identify capabilities and limitations of the inkjet digital textile printing market instead of competitors. Instead of 'strengths and weaknesses' of the market the principal investigator assessed the capabilities and limitations of the POD inkjet digital textile printing market as determined by the users. Market segmentation research was applied to determining the differences in opinion of capabilities and limitations and self-assessed skill levels among self-identified types of users of POD inkjet digitally printed textiles. Demographic information, such as age and gender, was gathered along with behavior and characteristics, such as length of time working with textiles, and self-assessed skill levels ranging from computer aided design skills to creating repeat patterns.

Quantitative research utilizes methodology, such as questionnaires or surveys distributed to a large number of respondents. The questionnaires are composed of formal questions with a given range of response options (Hair et al., 2008). Quantitative research methodology can be used for causal and descriptive research, as well as exploratory research. It is suited to designing and administering a questionnaire without relying on an interview or observer to interpret. Questionnaires and surveys created with quantitative methodology such as the survey instrument created and administered for this research are able to obtain information to test hypotheses and study the relationships between the market factors and behaviors (Hair et al., 2008). When applied to a large sample size of respondents, quantitative methodology allows for statistical projections of the results to the larger target population. Quantitative survey methodology provides factual information about the respondents that can then be applied to the larger target population (Hair et al., 2008). The results of the survey instrument demonstrate the respondents' demographic information, consumer behavior and skill levels and their perceived benefits and limitations of inkjet digital textile printing technology.

CHAPTER 4: RESULTS AND DISCUSSION

4. Results

Section 4.1. will first cover the respondent users' demographics and general consumer behavior. Section 4.2. will use statistical analysis using one-way ANOVA to analyze user perceptions and skill levels of aspects of the technology and to determine if there is a significant difference between self-assessed user groups.

4.1.Sample Characteristics

The survey instrument was distributed via an emailed newsletter to 50,000 newsletter subscribers. Of those 50,000, 13,500 of the email recipients opened the email and 725 accessed the survey instrument through the link in the newsletter. A total of 624 responders took the survey instrument. A demographic and behavioral profile of respondents was established through analysis of the survey using frequencies, means and statistical analysis. The majority of the responders identified themselves as female (95%), in the 50-65 (31%)

and 30-40 (28%) year old age range and had been working with textiles for at least 20 years (41%). Refer to Figures 12, 13 and 14.

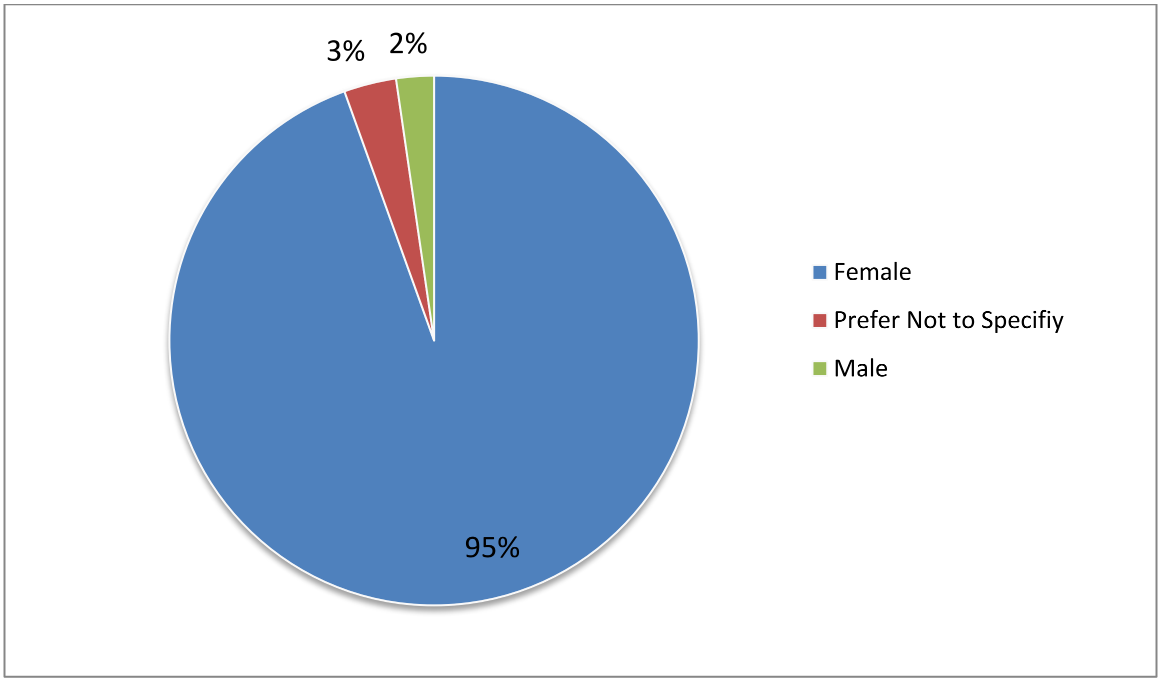


***Figure 12*: Gender in percentage of respondents**

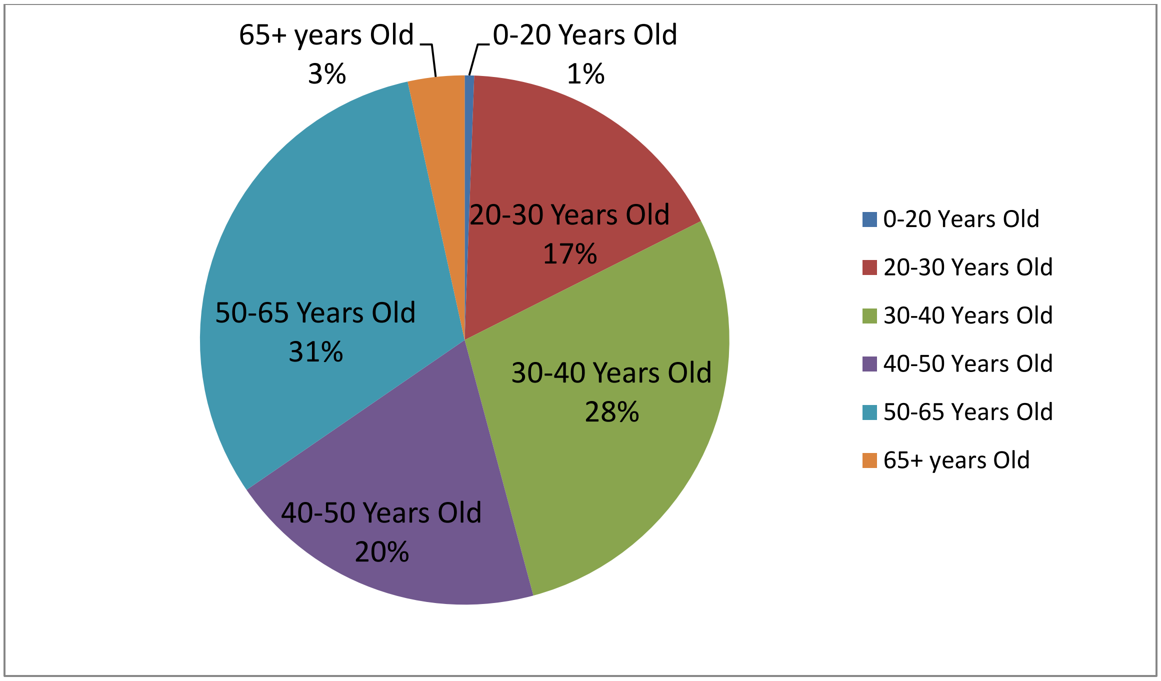


***Figure 13*: Age in percentage of respondents**

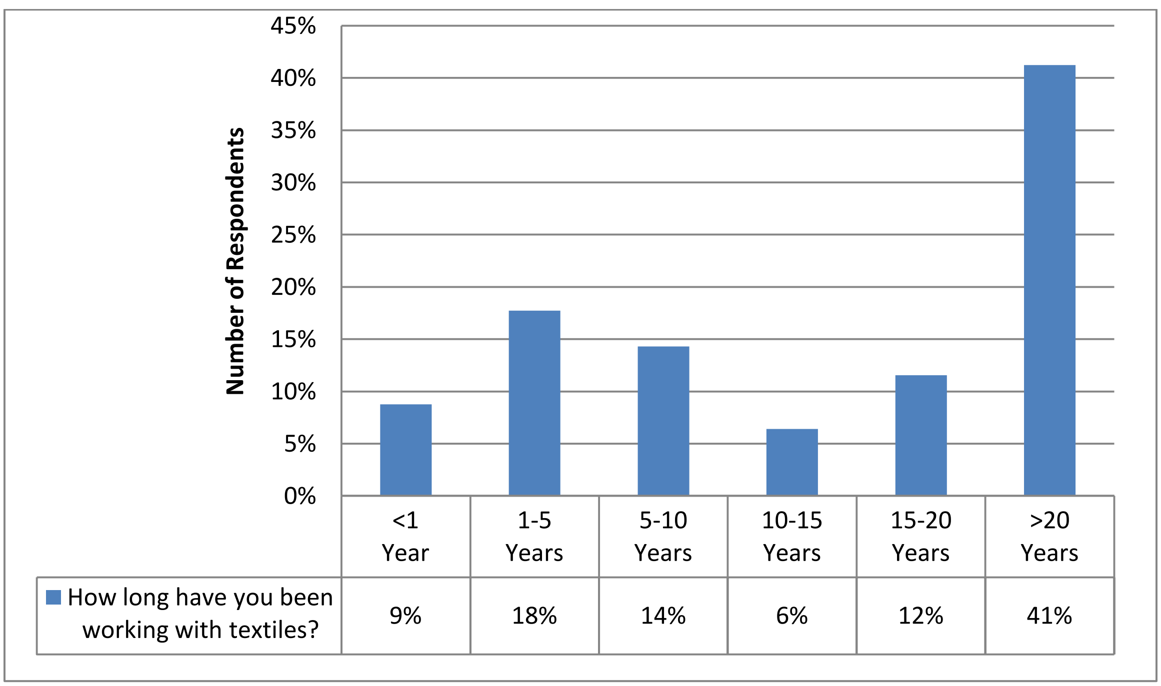


***Figure 14*: Respondents' length of time working with textiles in number of years in percentage of respondents**

It was also found that 50% of the respondents order less than one yard of fabric on average and 47% ordered one to five yards of fabric on average from the participating POD inkjet digital textile print bureau. Refer to Figure 15.

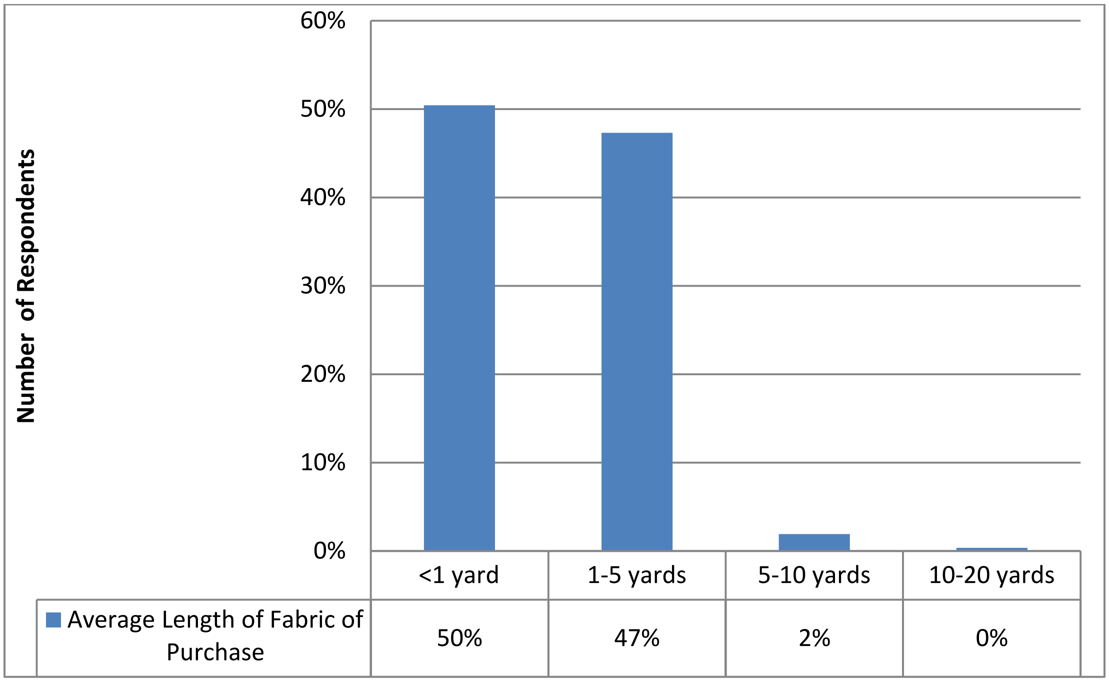


***Figure 15*: Respondents' average length of fabric purchased from POD digitally printed textiles company in percentage of respondents**

The majority of the respondents also self-identified as a Crafter (42%) with the niche market user types of Artist/Artisan (25%) and Designer (22%) being the second and third largest user type. Small Business Owner/Entrepreneur was chosen by only 11% of respondents, as evidenced in Figure 16. The user group Other was included in the survey instrument but was not included in the percentage, as it was the smallest number of respondents at 10%, or 34 respondents.

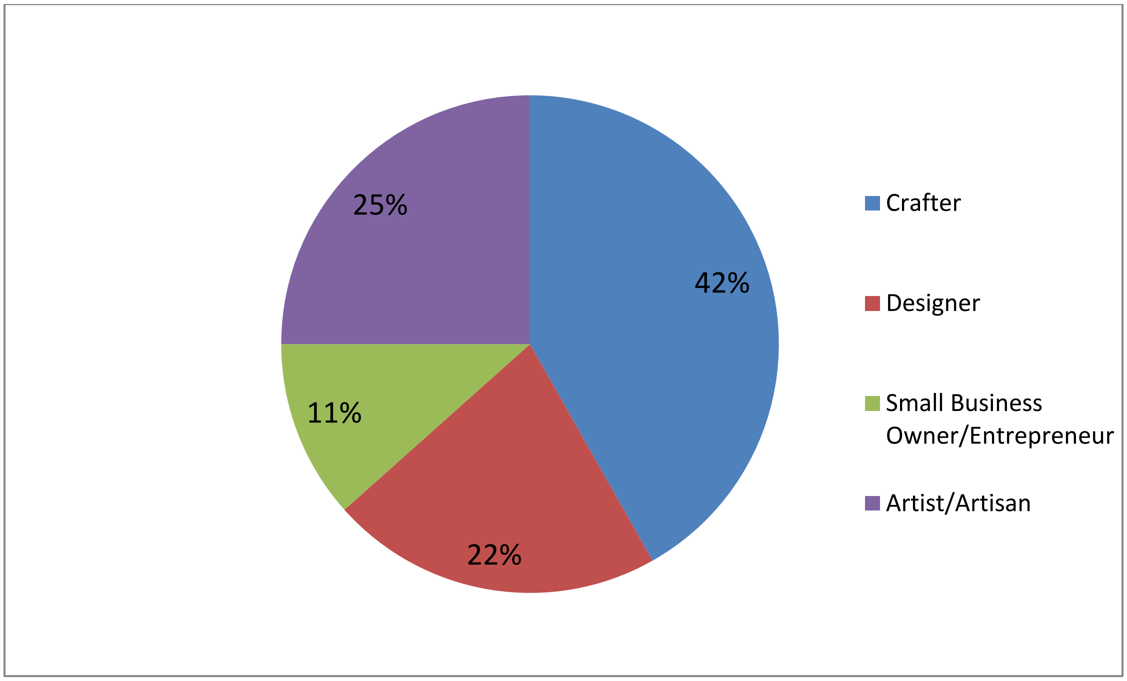
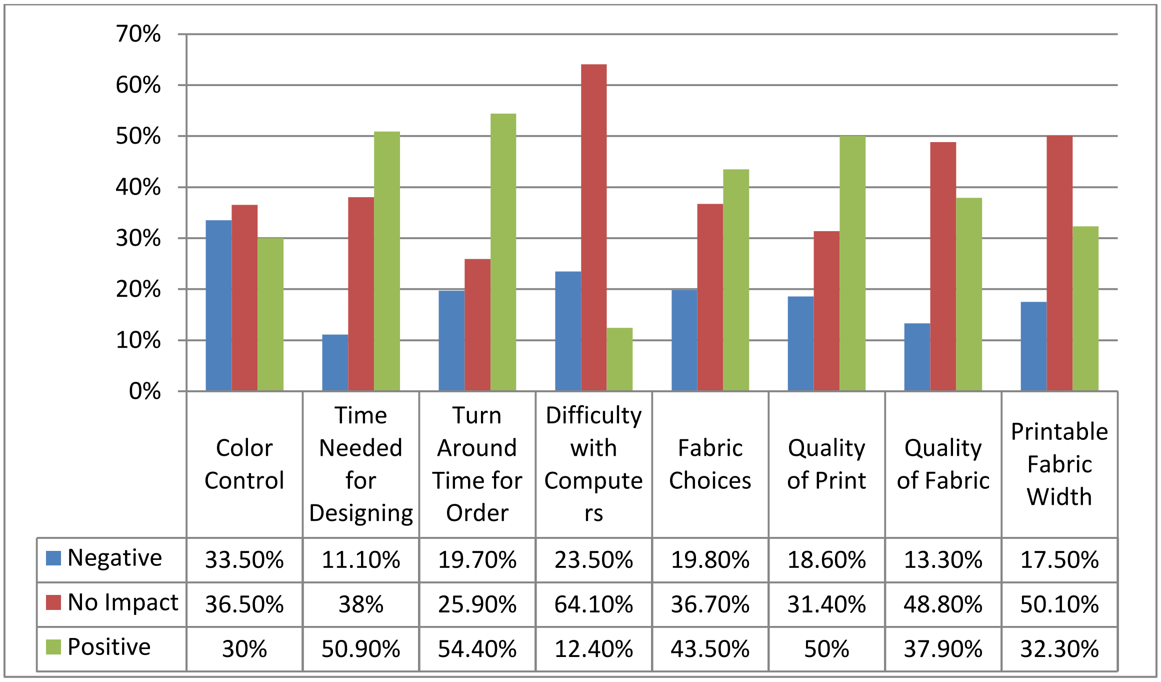


Figure 16**: Self identified niche market user types in percentage of respondents**

Respondents were asked in the survey to rank an assortment of aspects of inkjet digital textile printing using values of (1) for Negative Impact, (2) for No Impact, (3) for Positive Impact. The aspects chosen to be measured were as follows; color control, time needed for designing, turn-around time for order, difficulty with computers, fabric choices, quality of print, quality of fabric, printable fabric widths. It was found through analyzing the percentage of respondents' perceptions of impacts per aspect that users considered four out of eight aspects (Time Needed for Designing, Turn Around Time for Order, Fabric Choices, Quality of Print) to have a Positive Impact and four out of eight aspects (Color Control, Difficulty with Computers, Quality of Fabric, Printable Fabric Width) were considered to have No Impact as evident in Figure 17. Color Control was rated as having No Impact

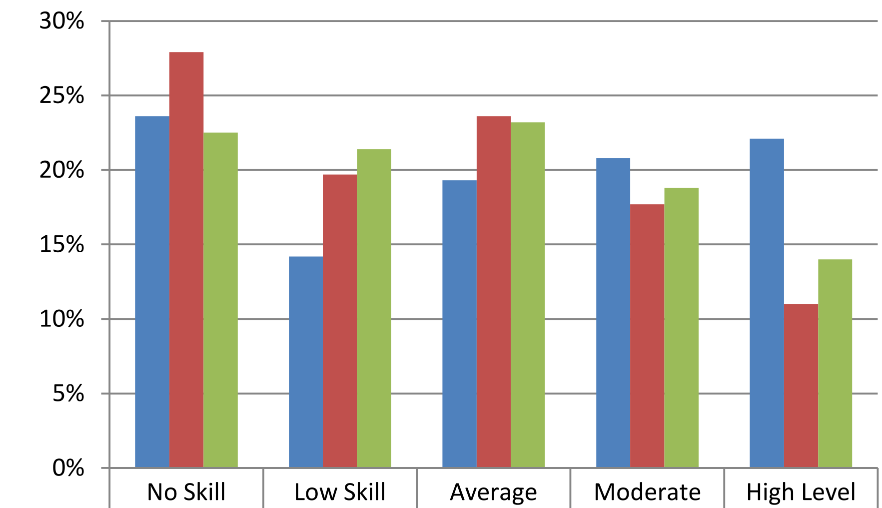
(36.50%) but had the highest Negative Impact percentage (33.50%) out of all eight aspects of POD inkjet digital textile printing. Difficulty with Computers had the highest No Impact percentage (64.10%).



	Color Control	Time Needed for Designing	Turn Around Time for Order	Difficulty with Computers	Fabric Choices	Quality of Print	Quality of Fabric	Printable Fabric Width
Negative	33.50%	11.10%	19.70%	23.50%	19.80%	18.60%	13.30%	17.50%
No Impact	36.50%	38%	25.90%	64.10%	36.70%	31.40%	48.80%	50.10%
Positive	30%	50.90%	54.40%	12.40%	43.50%	50%	37.90%	32.30%

***Figure 17*: Impact of digital printing aspects in percentage of respondents**

Respondents' self-assessed skill levels concerning three skill aspects were measured and analyzed. The three skills measured were user skill pertaining to CAD software systems, ability to control color and the ability to create repeating patterns. Responses were captured using a Likert Scale with skill levels rated from No Skill (1), Low Skill (2), Average (3), Moderate (4) and High (5). Respondents' self-assessed skill levels for these three aspects all ranked at or below average skill. The majority of respondents rated themselves as having No Skill with CAD software (23.60%) and Color Control (27.90%) while the majority of responders rated themselves as having Average Skill with Creating Repeat Patterns (23.20%) as evidenced in Figure 18.



	No Skill	Low Skill	Average	Moderate	High Level
CAD Software	23.60%	14.20%	19.30%	20.80%	22.10%
Color Control	27.90%	19.70%	23.60%	17.70%	11%
Creating Repeat Patterns	22.50%	21.40%	23.20%	18.80%	14%

***Figure 18*: Respondents' self assessed skill levels in percentage of respondents**

Self-assessed skill level means per self-identified niche market user groups were also analyzed using a Case Processing Analysis within PASW statistical software. The self-identified niche market user groups skill levels ranged from high to low; Designers were the highest ranking skill level, Artist/Artisan were the second highest ranking skill level, Small Business Owner/Entrepreneur were the second lowest ranking skill level and Crafters were the lowest ranking skill level. The Designer user group assessed themselves as having below average skill and low skill and scored the lowest in Color Control (1.97) and the highest in CAD software (2.43). The Small Business Owner/Entrepreneur user group assessed themselves as having average and below average skill levels and scored the lowest in Color Control (2.68) and Creating Repeat Patterns (2.68) and the highest in CAD software (3.11). The Artist/Artisan user group assessed themselves as having above average to below moderate skill levels and scored the lowest in Color Control (3.15) and the highest in CAD software (3.65). The Designer user group assessed themselves as having above average to moderate skill levels and scored the lowest in Color Control (3.66) and the highest in CAD software (4.1). Refer to Figure 19.

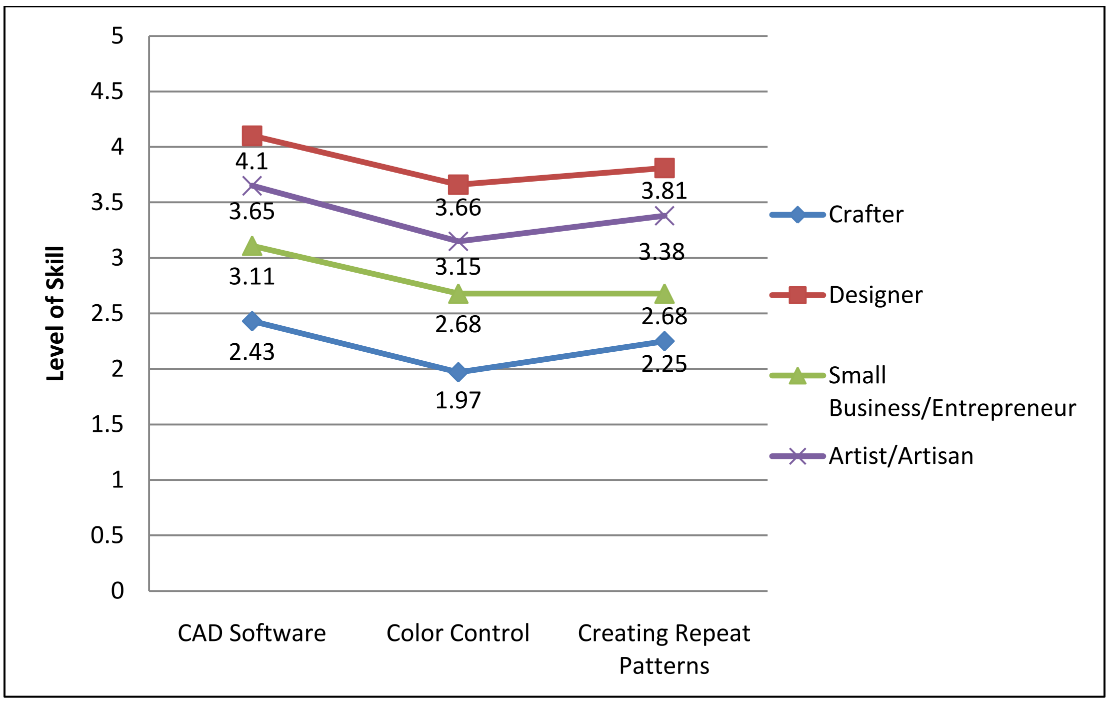


***Figure 19*: Self assessed mean skill level per niche market user type**

4.2. Statistical Analysis

The statistical software system PASW was used for in depth statistical analysis of the survey results. The research objectives were answered using one-way ANOVA and in cases where ANOVA models were significant, multiple comparisons using the Tamhane statistic test were used to examine the specific differences between niche market user types. Prior to performing ANOVA tests, descriptive statistics were performed for each objective.

The first null hypothesis for the analysis of the survey instrument results was: There is no relationship between the self-identified niche market user types and the self assessed skill levels pertaining to use of POD inkjet digitally printed textiles. To test the null hypothesis an ANOVA comparison was done with a Tamhane post test when the ANOVA comparison resulted in a significant result. Results were significant at the 0.05 and 0.0001 levels. Tested aspects of digitally printed textiles were rated using a Likert Scale with skill levels rated from No Skill (1), Low Skill (2), Average (3), Moderate (4) and High (5).It was found that among the self-identified niche market user types that there was significant difference among the self-assessed skill levels pertaining to use of inkjet digital textile printing.

The ANOVA model that examines the differences in CAD skill level among user types indicate a significant statistic ($F=30.603$, 3df, $p < .0001$). Refer to Table 1. Multiple Comparison Tests using Tamhane indicate significant differences specifically between the following user types in terms of skill level with CAD software: Crafter vs. Designer (mean difference = -1.672, $p<.0001$), Crafter vs. Artist/Artisan (mean difference = -1.220, $p<.0001$), Crafter vs. Small Business/Entrepreneur (mean difference =.993, $p<.007$), Designer vs. Small Business/Entrepreneur (mean difference= .993, p.<.007). Refer to Table 2. There was no significant difference between the following user groups in terms of skill level with CAD Software: Designer vs. Artist/Artisan (mean difference= .452, p.< .127), Small Business/Entrepreneur vs. Artist/Artisan (mean difference= -.541, p.< .368). Refer to Table 2.

Table 1: ANOVA Analysis of CAD Software Skill Level among User Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	155.167	3	51.722	30.603	.000***
Within Groups	545.897	323	1.690		
Total	701.064	326			

Note: Significant at the p<0.05 level. ***Significant at p<.0001 level

Table 2: Tamhane Post-Test, CAD Software Skill Level among User

(I) User Types	(J) User Types	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Crafter	Designer	-1.672*	.170	.000***	-2.12	-1.22
	S.B./ Entrepr.	-.679	.281	.110	-1.45	.09
	Artist/Artisan	-1.220*	.185	.000***	-1.71	-.73
Designer	Crafter	1.672*	.170	.000***	1.22	2.12
	S.B./ Entrepr.	.993*	.288	.007**	.21	1.78
	Artist/Artisan	.452	.196	.127	-.07	.97
S.B./ Entrepr.	Crafter	.679	.281	.110	-.09	1.45
	Designer	-.993*	.288	.007**	-1.78	-.21
	Artist/Artisan	-.541	.297	.368	-1.35	.27
Artist/Artisan	Crafter	1.220*	.185	.000***	.73	1.71
	Designer	-.452	.196	.127	-.97	.07
	S.B./ Entrepr.	.541	.297	.368	-.27	1.35

Note: Significant at p.< .05 level, S.B./ Entrepr.=Small Business Owner/Entrepreneur

*The mean difference is significant at the 0.05 level. ** Significant at p<0.05 level

***Significant at p<.0001 level

The ANOVA model that examines the differences in Color Control skill level among user types indicate a significant statistic (F=36.543, 3df, p.< .0001). Refer to Table 3. Multiple Comparison Tests using Tamhane indicate significant differences specifically between the following user types in terms of skill level with Color Control: Crafter vs. Designer (mean difference = -1.692, p.< .0001), Crafter vs. Artist/Artisan (mean difference = -1.178, p.<.0001), Crafter vs. Small Business/Entrepreneur (mean difference = -.714, p.< .039), Designer vs. Small Business/Entrepreneur (mean difference = .978, p.<.003), Designer vs. Artist/Artisan (mean difference = .514, p.< .043). Refer to Table 4. There was no significant difference between the following user groups in terms of skill level with Color Control: Small Business/Entrepreneur vs. Artist/Artisan (mean difference = -.464, p.< .438). Refer to Table 4.

Table 3: ANOVA Analysis of Color Control Skill Levels among User Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	153.755	3	51.252	36.543	.000***
Within Groups	450.202	321	1.402		
Total	603.957	324			

Note: Significant at the p<0.05 level. ***Significant at p< 0.0001 level

Table 4: Tamhane Post-Test, Color Control Skill Level among User Groups

(I) User Types	(J) User Types	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Crafter	Designer	-1.692*	.160	.000***	-2.12	-1.26
	S.B./ Entrepr.	-.714*	.252	.039**	-1.40	-.02
	Artist/Artisan	-1.178*	.169	.000***	-1.63	-.73
Designer	Crafter	1.692*	.160	.000***	1.26	2.12
	S.B./ Entrepr.	.978*	.266	.003**	.25	1.70
	Artist/Artisan	.514*	.189	.043**	.01	1.02
S.B./ Entrepr.	Crafter	.714*	.252	.039**	.02	1.40
	Designer	-.978*	.266	.003**	-1.70	-.25
	Artist/Artisan	-.464	.271	.438	-1.20	.27
Artist/Artisan	Crafter	1.178*	.169	.000***	.73	1.63
	Designer	-.514*	.189	.043	-1.02	-.01
	S.B./ Entrepr.	.464	.271	.438	-.27	1.20

Note: Significant at p.< .05 level, S.B./ Entrepr.=Small Business Owner/Entrepreneur

*The mean difference is significant at the 0.05 level. ** Significant at p<0.05 level

***Significant at p<.0001 level

The ANOVA model that examines the differences in Creating Repeat Patterns skill level among user types indicate a significant statistic (F=30.583, 3df, p<.0001). Refer to Table 5. Multiple Comparison Tests using Tamhane indicate significant differences specifically between the following user types in terms of skill level with Creating Repeat Patterns: Crafter vs. Designer (mean difference = -1.561, p.< .0001), Crafter vs. Artist/Artisan (mean difference = -1.121, p.<.0001), Designer vs. Small Business/Entrepreneur (mean difference = 1.130, p.< .0001). Refer to Table 6. There was no significant difference between the following user groups in terms of skill level with Creating Repeat Patterns: Crafter vs. Small Business/Entrepreneur (mean difference = -.430, p.< .378), Designer vs. Artist/Artisan (mean difference = .439, p.< .173), Small Business/Entrepreneur vs. Artist/Artisan (mean difference = -.691, p.< .060). Refer to Table 6.

Table 5: ANOVA Analysis of Creating Repeat Patterns Skill Levels among User Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	134.140	3	44.713	30.583	.000***
Within Groups	464.919	318	1.462		
Total	599.059	321			

Note: Significant at the p<0.05 level. ***Significant at p<0.0001 level

Table 6: Tamhane Post-Test, Creating Repeat Patterns Skill Level among User Groups

(I) User Types	(J) User Types	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Crafter	Designer	-1.561*	.169	.000***	-2.01	-1.11
	S.B./ Entrepr.	-.430	.238	.378	-1.08	.22
	Artist/Artisan	-1.121*	.176	.000***	-1.59	-.65
Designer	Crafter	1.561*	.169	.000***	1.11	2.01
	S.B./ Entrepr.	1.130*	.257	.000***	.43	1.83
	Artist/Artisan	.439	.202	.173	-.10	.98
S.B./ Entrepr.	Crafter	.430	.238	.378	-.22	1.08
	Designer	-1.130*	.257	.000***	-1.83	-.43
	Artist/Artisan	-.691	.262	.060	-1.40	.02
Artist/Artisan	Crafter	1.121*	.176	.000***	.65	1.59
	Designer	-.439	.202	.173	-.98	.10
	S.B./ Entrepr.	.691	.262	.060	-.02	1.40

Note: Significant at p.< .05 level, S.B./ Entrepr.=Small Business Owner/Entrepreneur

*The mean difference is significant at the 0.05 level. ***Significant at p<.0001 level

The second null hypothesis for the analysis of the survey instrument results was: There is no relationship between the self-identified niche market user types and the perceived capabilities and limitations of POD inkjet digitally printed textiles. To test the null hypothesis an ANOVA comparison was done with a Tamhane post test if the ANOVA comparison resulted in a significant result. Results were significant at the 0.05 level. Tested aspects of POD inkjet digitally printed textiles were rated using values of (1) Negative Impact, (2) No Impact and (3) Positive Impact.

The first aspect analyzed was the issue of Color Control. Controlling colors with inkjet digital printing of textiles is of great importance for quality control and artistic issues. It was found that among the self-identified niche market user types that there was no significant difference among the perceived limitations or capabilities of this aspect of inkjet digital textile printing. The ANOVA model that examines the differences in Color Control limitations or capabilities among user types indicate a non-significant statistic ($F=.966$, 3df, $p.<.409$). Refer to Table 7.

Table 7: ANOVA Analysis of Impact of Color Control among User Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.902	3	.634	.966	.409
Within Groups	204.715	312	.656		
Total	206.617	315			

Note: Significant at the p<0.05 level.

The second aspect analyzed was the issue of Time Needed for Designing. It was found that among the self-identified niche market user types that there was no significant difference among the perceived limitations or capabilities of this aspect of POD inkjet digital textile printing. The ANOVA model that examines the differences in Time Needed for Designing limitations or capabilities among user types indicate a non-significant statistic (F=.168, 3df, p.<.918). Refer to Table 8.

Table 8: ANOVA Analysis of Impact of Time Needed for Designing among User Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.233	3	.078	.168	.918
Within Groups	146.520	317	.462		
Total	146.754	320			

Note: Significant at the p<0.05 level.

The third aspect analyzed was the issue of Turn-Around Time for Order. Turn-Around Time, or time it takes to manufacture and ship the product from receiving the digital file to printing, post-treating and shipping is a vital benefit of inkjet digital textile printing compared to conventional printing. However, as many users of the POD inkjet digital printing company surveyed may not be aware of this advantage it was decided to measure their perception of whether the turn-around time was a limitation or if they perceived it as a capability. It was found that among the self-identified niche market user types that there was no significant difference among the perceived limitations or capabilities of this aspect of digital textile printing. The ANOVA model that examines the differences in Turn-Around Time for Order limitations or capabilities among user types indicate a non-significant statistic (F=1.058, 3df, p.<.367). Refer to Table 9.

Table 9: ANOVA Analysis of Impact of Turn-Around Time for Order among User Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.006	3	.669	1.058	.367
Within Groups	200.299	317	.632		
Total	202.305	320			

Note: Significant at the p<0.05 level.

The fourth aspect analyzed was the issue of Difficulty with Computers. It was found that among the self-identified niche market user types that there was no significant difference among the perceived limitations or capabilities of this aspect of POD inkjet digital textile printing. The ANOVA model that examines the differences in Difficulty with Computers limitations or capabilities among user types indicate a non-significant statistic (F=1.529, 3df, p.<.207). Refer to Table 10.

Table 10: ANOVA Analysis of Impact of Difficulty with Computers among User Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.648	3	.549	1.529	.207
Within Groups	113.142	315	.359		
Total	114.790	318			

Note: Significant at the p<0.05 level.

The fifth aspect analyzed was the issue of Fabric Choices. While pigment-based inkjet digital textile colorants are capable of printing on a wide variety of substrates, economically most businesses offering inkjet digital textile printing are not able to offer all colorant, fiber and fabric types desired by users. It was found that among the self-identified niche market user types that there was no significant difference among the perceived limitations or capabilities of this aspect of POD inkjet digital textile printing. The ANOVA model that examines the differences in Fabric Choices limitations or benefits among user types indicate a non-significant statistic (F=.938, 3df, p.<.423). Refer to Table 11.

Table 11: ANOVA Analysis of Impact of Fabric Choices among User Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.641	3	.547	.938	.423
Within Groups	183.763	315	.583		
Total	185.404	318			

Note: Significant at the p<0.05 level.

The sixth aspect analyzed was the issue of Print Quality. It was found that among the self-identified niche market user types that there was no significant difference among the perceived limitations or capabilities of this aspect of POD inkjet digital textile printing. The ANOVA model that examines the differences in Print Quality limitations or capabilities among user types indicate a non-significant statistic (F=.479, 3df, p.<.697). Refer to Table 12.

Table 12: ANOVA Analysis of Impact of Quality of Print among User Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.855	3	.285	.479	.697
Within Groups	187.214	315	.594		
Total	188.069	318			

Note: Significant at the p<0.05 level.

The seventh aspect analyzed was the issue of Fabric Quality. It was found that among the self-identified niche market user types that there was no significant difference among the perceived limitations or capabilities of this aspect of POD inkjet digital textile printing. The ANOVA model that examines the differences in Fabric Quality limitations or capabilities among user types indicate a non-significant statistic (F=1.638, 3df, p.<.181). Refer to Table 13.

Table 13: ANOVA Analysis of Impact of Quality of Fabric among User Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.262	3	.754	1.638	.181
Within Groups	145.011	315	.460		
Total	147.273	318			

Note: Significant at the p<0.05 level.

The eighth aspect analyzed was the issue of Printable Fabric Widths. It was found that among the self-identified niche market user types that there was no significant difference among the perceived limitations or capabilities of this aspect of POD inkjet digital textile printing. The ANOVA model that examines the differences in Printable Fabric Widths limitations or capabilities among user types indicate a non-significant statistic (F=.268, 3df, p.<.848). Refer to Table 14.

Table 14: ANOVA Analysis of Impact of Printable Fabric Widths among User Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.400	3	.133	.268	.848
Within Groups	157.147	316	.497		
Total	157.547	319			

Note: Significant at the $p<0.05$ level.

In conclusion, it was found that the eight potential capabilities and limitations of POD inkjet digital textile printing were considered to be neutral aspects with no impact on utilizing the technology and leaning towards being beneficial. There was no difference of opinion between the four self-assessed niche market user groups concerning the capabilities and limitations of inkjet digital textile printing. Analysis of self-assessed skill levels of niche market users showed there was a significant difference between niche market user types and their self-assessed skill levels.

CHAPTER 5: CONCLUSION

5. Conclusion

The objectives of this research were to evaluate and determine the capabilities and limitations of POD inkjet digital textile printing as assessed by niche market user groups. The main objective of this research is to measure the capabilities and limitations of POD inkjet digitally printed textiles as perceived by the niche market users. The results of the survey instrument demonstrate that the research can be considered successful in capturing users perceptions of capabilities and limitations of various aspects of POD inkjet digital textile printing. Capabilities of the technology were considered to be aspects that rated as having a Positive Impact and limitations where aspects that rated as having a Negative Impact. Respondents' self-assessed skill levels pertaining to the use of inkjet digital textile printing such as CAD software, ability to control color and create repeat patterns was also included in the research to determine what capabilities and limitations are on the user end. Analysis of self-assessed skill levels of self-identified niche market user types revealed a significant difference between self-identified niche market user types and their self-assessed skill levels.

5.1. Capabilities

From the results of the research it is evident that some aspects of POD inkjet digital textile printing are considered capabilities by the niche market users. Objective One of the research was to determine the capabilities and limitations of different aspects of inkjet digitally printed textiles as measured by the opinions of a group of users. It was found that capabilities or aspects with Positive Impacts were; Time Needed for Designing, Turn-Around Time for Order, Fabric Choices and Quality of Print. Mean self-assessed user skill levels were found to be limitations with the majority of respondents ranking themselves as having Average Skill with Creating Repeat Patterns. Objective Two of the research was to determine if there is a difference in perceived capabilities and limitations of digitally printed textiles per self-identified niche market user types among the provided four categories; Crafters, Designers, Artist/Artisan, Small Business Owners/Entrepreneurs. Comparisons between the four user groups showed no difference of opinion of perceived capabilities and limitations (Positive or Negative Impacts) of inkjet digital textile printing. However, it was found that there were significant differences between niche market user groups in self assessed skill levels. The Designer niche market user group demonstrated that skill levels in CAD software, color control and creating repeat patterns can be considered capabilities of inkjet digital textile printing as this group self-assessed themselves with the highest skill level.

5.2. Limitations

From the results of the research it is evident that few aspects of POD inkjet digital textile printing are considered limitations by the niche market users. Objective One of the research was to determine the capabilities and limitations of different aspects of inkjet digitally printed textiles as measured by the opinions of a group of users. Of the aspects surveyed to determine whether users perceived the aspect as a capability or limitation, none ranked as limitations. Instead, those aspects that were not capabilities with a Positive Impact were considered neutral aspects with No Impact. It was found that aspects rating as having No Impact were; Color Control, Difficulty with Computers, Quality of Fabric, Printable Fabric Width. Mean self-assessed user skill levels were found to be limitations with the majority of respondents ranking themselves as having No Skill with CAD software and Color Control. Objective 2 of the research was to determine if there is a difference in perceived capabilities and limitations of digitally printed textiles per self-identified niche market user types among the provided four categories; Crafters, Designers, Artist/Artisan, Small Business Owners/Entrepreneurs. There was no difference in perceived limitations per aspect. Results of the research found a significant difference niche market user groups and their self-assessed skill levels.

5.3. Recommendations & Future Research

The results from this research provide insight into niche market users' perceptions of capabilities and limitations encountered in the use of a POD inkjet digital textile printing company. As few limitations of POD inkjet digital textile printing were found, future research can focus on the limitations of user skill levels, especially in regards to CAD software and skill levels of the Crafter niche market user group. Future research could be used to determine if further education and training is necessary to best use inkjet digital textile printing. Training modules to train users on aspects of inkjet digital textile printing could demonstrate future methods of measuring and raising user skill levels. As this research was exploratory future researchers could continue to look at niche markets and the niche manufacturing such as POD capabilities of inkjet digital textile printing technology. Future research in inkjet digital textile printing can examine possibilities of production level printers, which may replace conventional textile printing technology (Glover, 2004). POD inkjet digital textile printing companies off a variety of colorants, some companies only offer pigment-based colorants while others offer both pigment and dye-based colorants. Future research can examine the relationship between colorant type and the users' perception of color control importance and print quality.

There were limitations and issues encountered during the research that will be improved upon during subsequent studies. The POD inkjet digital textile printing company whose users were surveyed changed their fabric choices during and after the survey collection period and now offers a wider variety of fabric and fiber types. This may have impacted some respondents' answers to the impact of fabric choice and quality and respondents may answer differently if questioned again. Therefore the reproducibility of the survey instrument is hampered. The participating company uses pigment-based colorants instead of dye-based colorants. The difference in color gamuts of pigment versus dye-based colorants may have impacted users' perceptions of color and print quality. Only one user base from one POD inkjet digital textile printing company were surveyed. If multiple user bases from a variety of POD inkjet digital textile print companies were surveyed the results may differ, as different companies focus on different market segments, i.e. crafters or designers.

Chapter 6: REFERENCES

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APPENDICES

Appendix A: IRB Approval

North Carolina State University is a land-grant university and a constituent institution of the University of North Carolina

Office of Research and Innovation
Division of Research Administration

Campus Box 7514
Raleigh, North Carolina 27695-7514

NC STATE UNIVERSITY

919.515.2444 (phone)
919.515.7721 (fax)

From: Carol Mickelson, IRB Coordinator
North Carolina State University
Institutional Review Board

Date: October 25, 2010

Project Title: Determining the capabilities and limitations that digitally printed textiles have on American niche handicraft markets.

IRB#: 1697

Dear Katherine Polston,

The research proposal named above has received administrative review and has been approved as exempt from the policy as outlined in the Code of Federal Regulations (Exemption: 46.101. b.2). Provided that the only participation of the subjects is as described in the proposal narrative, this project is exempt from further review.

NOTE:

1. This committee complies with requirements found in Title 45 part 46 of The Code of Federal Regulations. For NCSU projects, the Assurance Number is: FWA00003429.

2. Any changes to the research must be submitted and approved by the IRB prior to implementation.

3. If any unanticipated problems occur, they must be reported to the IRB office within 5 business days.

Please forward a copy of this letter to your faculty sponsor, if applicable. Thank you.

Sincerely,

Carol Mickelson

Carol Mickelson
NC State IRB

Appendix B: Survey Instrument

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1. Consent Form

*1. **North Carolina State University**
INFORMED CONSENT FORM for RESEARCH
Title of Study: Determining the capabilities and limitations that digitally printed textiles have on American niche handicraft markets.

Principal Investigator: Katherine Polston Faculty Sponsor: Lisa Parrillo-Chapman

You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time. The purpose of research studies is to gain a better understanding of a certain topic or issue. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. If at any time you have questions about your participation, do not hesitate to contact the researcher Katherine Polston or Lisa Parrillo-Chapman.

The purpose of this study is to provide a greater understanding of digitally printed textiles in the American niche handicraft market. The survey results will become part of the published master's research conducted by Katherine Polston. If you agree to participate in this study, you will be asked to complete the following questions.

The information in the study records will be kept strictly confidential. Data will be stored securely on a password protected server accessible only by the principal investigators. SLL will be used for transmitting survey results. No reference will be made in oral or written reports which could link you to the study.
There is no monetary compensation. You will not receive anything for participating, other than the knowledge that you are contributing to building a greater body of work about digitally printed fabrics and niche markets. There are no foreseeable risks associated with completing this survey or participating in the case study.

If you have questions at any time about the study or the procedures, you may contact the researcher, Katherine Polston, at the College of Textiles, NCSU, Raleigh NC 27695-8301. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this

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project, you may contact Dr. Arnold Bell, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/515-4420).

By checking the "I accept" box I acknowledge I have read and understand the above information and am over the age of 18. I may print a copy of this agreement for my records. I agree to participate in this study with the understanding that I may withdraw at any time.

- ◯ I accept
- ◯ I do not accept

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2.

1. What is the average quantity of fabric you typically purchase from [redacted]?

- Less than 1 yard
- 1-5 yards
- 5-10 yards
- 10-20 yards
- 20-30 yards
- 30-40 yards
- 40+ yards

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3.

This set of questions will be about your experiences with digitally printed fabrics and your design skills.

1. Please rank the following statement: You consider yourself knowledgeable of fabric qualities. (ex: drape and stretchiness)

- ○ Disagree
- ○ Somewhat Disagree
- ○ Neutral
- ○ Somewhat Agree
- ○ Agree

2. How long have you been working with textiles?

- ○ 20+ years
- ○ 15-20 years
- ○ 10-15 years
- ○ 5-10 years
- ○ 1-5 years
- ○ Less than 1 year

3. Please rate how often you implement the following types of color control:

	Never	Rarely	Sometimes	Often	Very Often
Creating a color palette	○	○	○	○	○
Creating multiple colorways	○	○	○	○	○
Adjusting for printed color shift	○	○	○	○	○
Calibrating your monitor	○	○	○	○	○

4. Please choose the answer that best describes your skill level with the following tools and tasks for textile design.

	No skill	Low Skill	Average	Moderate	High level
CAD software (e.g. Photoshop)	○	○	○	○	○
Color Control	○	○	○	○	○
Creating Repeat Patterns	○	○	○	○	○

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5. Are you familiar with different types of color modes (e.g. RGB vs LAB etc...)

- ◯ Yes
- ◯ No

6. Are you familiar with the fact that colors will change from the display on a computer screen to what will be printed out?

- ◯ Yes
- ◯ No

7. How often do you order samples of your designs before purchasing larger orders to ensure color and dimensions are correct?

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Very Often

8. Have you ordered a [redacted] color chart before?

- ◯ Yes
- ◯ No

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4.

1. Why have you not ordered a color chart?

- ◯ Felt I didn't need it
- ◯ Too confusing to use
- ◯ Not familiar with color shift
- ◯ Don't care if colors change

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5. Capabilities & Limitations

1. How do you feel that digital printing impacts the following factors when creating custom fabric?

	Negatively	No Impact	Positively
Color control	◯	◯	◯
Time needed for designing	◯	◯	◯
Turn around time for order	◯	◯	◯
Difficulty with computers	◯	◯	◯
Fabric choices	◯	◯	◯
Quality of print	◯	◯	◯
Quality of fabric	◯	◯	◯
Printable fabric widths	◯	◯	◯

2. Please add any comments concerning the above factors:

3. Are you aware that there are different types of colorants (inks and dyes) used in digitally printed textiles?

◯ Yes

◯ No

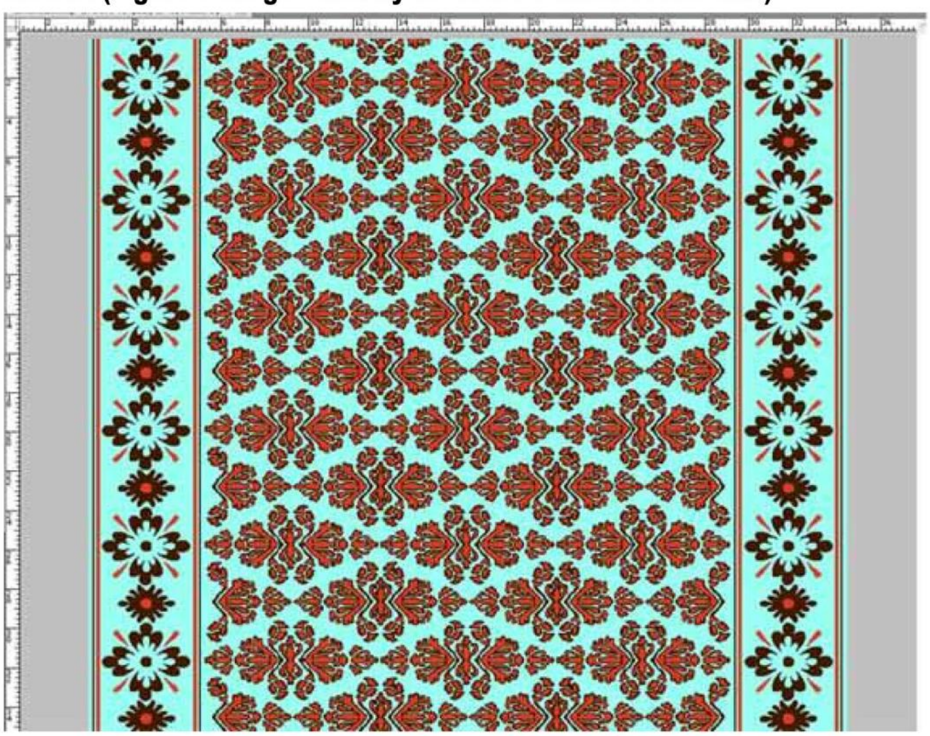
4. How familiar are you with the different characteristics of the following colorants currently used in digitally printed textiles (e.g. color ranges and quality, which textile fibers are compatible):

	Unfamiliar	Somewhat Unfamiliar	Neutral	Somewhat Familiar	Familiar
Acid Dye Based	◯	◯	◯	◯	◯
Reactive Dye Based	◯	◯	◯	◯	◯
Nano-Pigment Based	◯	◯	◯	◯	◯
Disperse Dye Based	◯	◯	◯	◯	◯

5. Please rate the following statement: The following items attract you to digitally printed fabrics.

	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree
Costs relative to other designer/custom fabrics	○	○	○	○	○
Personalized service	○	○	○	○	○
Turn-around time	○	○	○	○	○
Unlimited colors	○	○	○	○	○
No restriction on repeat sizes	○	○	○	○	○
Create designs specifically for the end use	○	○	○	○	○
No minimum order quantity	○	○	○	○	○
Novel and unique prints	○	○	○	○	○

Here is an example of a design created to fit within a yard of fabric and print along the border. (Figure 1-image courtesy of N.C.S.U. student Allie Tate)



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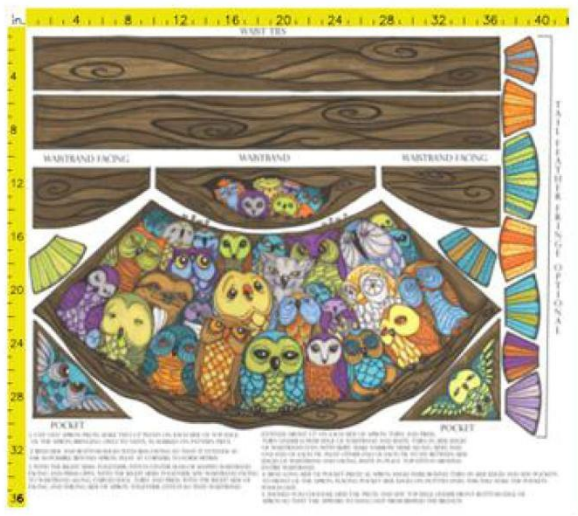
6. Do you create or order designs which are formatted for specific fabric sizes? (ex: to fit into 1 yard, please see Figure 1 above)

- ◯ Yes
- ◯ No
- ◯ Not Sure

Here is an example of a design created specifically for the end product, in this case an apron. (Figure 2-"Owl Be Darned!" by Cean Irminger)



7. Do you create designs which are formatted specifically for the end product? (ex: cut and sew apron patterns etc...., see Figure 2 above)

- ◯ Yes
- ◯ No
- ◯ Not Sure

8. Do you feel that the current method of repeat and layout on [redacted]'s website makes it easy to create designs specifically for the end product?

- ◯ Yes
- ◯ No

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6.

This set of questions will be about what you use Spoonflower fabric for.

1. How often do you use the following items to create your own designs for [redacted] fabric:

	Never	Rarely	Sometimes	Often	Very Often
[redacted] Marketplace (available via Creative Commons)	◯	◯	◯	◯	◯
Own designs (either hand-drawn or computer designed)	◯	◯	◯	◯	◯
Photo and/or Photo manipulation	◯	◯	◯	◯	◯
A hired designer	◯	◯	◯	◯	◯
Images from the internet	◯	◯	◯	◯	◯

2. How often do you use the [redacted] Marketplace to purchase others' designs?

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Often
- ◯ Very Often

3. How often do you use [redacted] fabric for the following:

	Never	Rarely	Sometimes	Often	Very Often
Garments & Apparel	◯	◯	◯	◯	◯
Accessories (Handbags, etc...)	◯	◯	◯	◯	◯
Pet accessories (Dog beds, cat-nip toys etc...)	◯	◯	◯	◯	◯
Large home furnishings (Drapes, bedding etc...)	◯	◯	◯	◯	◯
Small home furnishings (hand-towels, throw pillows)	◯	◯	◯	◯	◯
Art work (Wall hangings etc...)	◯	◯	◯	◯	◯
Quilts (Art)	◯	◯	◯	◯	◯
Quilts (Functional)	◯	◯	◯	◯	◯

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4. How often do you use [redacted] fabric for the following types of apparel:

	Never	Rarely	Sometimes	Often	Very Often
Infant	◯	◯	◯	◯	◯
Children's	◯	◯	◯	◯	◯
Women's	◯	◯	◯	◯	◯
Men's	◯	◯	◯	◯	◯
Costumes/Historical Costumes	◯	◯	◯	◯	◯

5. For what purpose(s) do you use [redacted] fabric?

◯ Personal Use

◯ Re-Sale

◯ Both

7.

1. How often do you use the following avenues to re-sell fabric ordered from [redacted]:

	Never	Rarely	Sometimes	Often	Very Often
Personal web-site/blog	○	○	○	○	○
3rd party web-site such as Etsy	○	○	○	○	○
Auction web-site such Ebay	○	○	○	○	○
Local retailers (Boutiques, vintage stores etc…)	○	○	○	○	○
Fairs and markets (local and national)	○	○	○	○	○

2. How often do you resell the following:

	Never	Rarely	Sometimes	Often	Very Often
Finished goods	○	○	○	○	○
Semi-finished goods (cut and prepped fat quarters, quilt kits etc…)	○	○	○	○	○
Unfinished goods (uncut yards)	○	○	○	○	○

3. Do you sell:

- ○ Locally (within your state of residence)
- ○ Regionally (within your state of residence and neighboring states)
- ○ Nationally (across many states)
- ○ Internationally

4. Which of the following reasons are important in your decision to sell:

	Not Important	Slightly Important	Neutral	Important	Very Important
Economic gain	○	○	○	○	○
Creative outlet/Self-expression	○	○	○	○	○
Hobby	○	○	○	○	○
Filling a niche market	○	○	○	○	○

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5. Of the following user types, which most closely describes you?

- ○ Crafter (Quilts etc...)
- ○ Designer
- ○ Small business/entrepreneur
- ○ Artist/Artisan

Other (please specify)

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8.

1. Do you own your own business?

- ◯ Yes
- ◯ No

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9.

1. Do you feel that you would be able to operate your business without access to a company such as [redacted]?

- ◯ Yes
- ◯ No

2. Would you agree that your business is successful?

- ◯ Disagree
- ◯ Somewhat Disagree
- ◯ Neutral
- ◯ Somewhat Agree
- ◯ Agree

3. Would you agree that [redacted]'s digitally printed fabrics positively impact your revenue?

- ◯ Disagree
- ◯ Somewhat Disagree
- ◯ Neutral
- ◯ Somewhat Agree
- ◯ Agree

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10. Demographic Information

1. Please fill in the following information

Company (if applicable)

ZIP:

2. What is your sex?

- Female
- Male
- Prefer not to specify

3. Please select your age below.

- 0-20 years
- 20-30 years
- 30-40 years
- 40-50 years
- 50-65 years
- 65+ years

4. What is the level of Internet availability in your household?

- None (No computers)
- Limited (1-2 computers)
- Wide (3+ computers)

Other (please specify)

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11.

Thank you for participation in this survey. Please make sure that you have answered all questions as completely as possible. The information you have provided is very important to the future of this industry and your input is greatly appreciated.

1. Do you have any questions or comments about this survey?

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12. Thank you!

Thank you for your time and participation! [redacted] is offering participants in this survey a chance to enter a drawing to win a yard of free, custom fabric. You will be redirected to the raffle page upon completion.