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# Technical Illustration: The Changes and Challenges Presented by Advancements in Technology

Cindy Caudill
*University of Central Florida*

# TECHNICAL ILLUSTRATION: THE CHANGES AND CHALLENGES PRESENTED BY ADVANCEMENTS IN TECHNOLOGY

by

CINDY M. CAUDILL
B.A. University of Central Florida, 2011
A.A. Polk State College, 2007

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# ABSTRACT

This thesis investigates the changes and challenges technology has created in the field of technical illustration. Technical illustration includes the fields of technical drawing as well as scientific and medical illustration. Previously, technical illustrators learned and used traditional illustration methods, without the aid of computers. However, technology has rapidly entered the field and has changed the education, work environment, skills, and role of the technical illustrator. I note both the benefits and disadvantages that current technical illustrators are facing in their work. I explore both sides of the digital media and traditional art debate while focusing on the technical illustrator's role, tools and methods used in the illustration process, education, idea-generation, and the future of technical illustration. By emphasizing the issues associated with the incorporation of digital media into traditional methods, I hope to bring awareness to the transformation of technical illustration and the future of this discipline.

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# CHAPTER 1: INTRODUCTION

Technical illustrations can be found everywhere from textbooks to educate future generations to manuals that provide instructions for product users to blueprints that direct the formation of our cities. Technical, scientific, and medical illustrations are used to educate and explain by providing a visual depiction of subject matter and processes. Since technical illustrations are a key component in the field of technical communication, it is critical that these illustrations maintain quality and accuracy so that the information presented is exact.

For many years, technical illustrations were confined to printed mediums. However, due to the increase in technology, the field of technical illustration has seen many changes while embracing digital art as a new medium. Although many efforts have been made to bridge the gap between technology and the arts, artists have encountered new difficulties both with the implementation of computer technology and in embracing change. As Tracey Bowen notes in her study of the production of digital art, some artists encounter a “tug-of-war between the seductive authority of digital imaging programs and the web, and the artists' yearning for the physicality of the material art object and being immersed in its hand-made realization” (224).Technology has continued to progress into the arts despite reluctance and issues. Technical illustration has become entwined with the world of computer technology for use in websites, software, and electronic documents. Technology and illustration are dependent upon one another: each balancing on the other to progress and remain relevant. Planning and building new technology requires accurate illustrations of the parts and process. Additionally, illustrations must now be digitized for distribution in this electronic world. Technological advancements have pushed illustrators to trade in their pens and paper for tablets and monitors. Both fields have come to the point where each cannot grow and function without the other.

## Purpose

This thesis investigates the changes in the field of technical illustration due to the rapid increase in technology, and to determine how these changes have influenced the field of technical communication. Since computer technology has become a common part of the workplace, technical illustration has seen a major shift in tools, techniques, and training. These changes have brought about new benefits and challenges for the working illustrator and will continue to mold the field of technical illustration.

Chapter One offers a brief literature review of the issues surrounding technology in technical illustration, as well as provide a definition of technical illustration. The definition includes information such as the purpose of technical illustration, variations in illustrations, and the types of technical illustrators. The chapter concludes with a short history of technical illustration and the establishment of technical illustration as a field of study.

Chapter Two discusses traditional methods of technical illustration including the tools and knowledge required. There will also be an introduction to digital art as a medium. This chapter also outlines the tools and knowledge required of the digital artist. After each section, there is also a discussion of the benefits and difficulties posed by both traditional and digital methods. Some of the topics noted include skills, cost, and applicability.

Chapter Three addresses the issues found within technical illustration education, specifically the question of teaching traditional versus digital methods. It also discusses the work-related challenges due to the rapid development in technology such as changes in work-load and deadlines, quality, and adjustments to new tools and software. There is also a section discussing the necessity and changing role of the sketchbook in the preliminary stages of design. Chapter Three concludes with interviews with three working technical illustrators.

Chapter Four concludes the thesis with a summary of the key points as well as a discussion of the past, present, and future adversities encountered by technical illustrators due to the development of technology. It also discusses future research possibilities in the education of technical illustrators and the effects of deskilling on the field of technical communication. Examining such issues might provide insight into the struggles facing current and future technical illustrators and offer solutions to the traditional methods versus digital media debate.

## A Brief History of Technical Illustration

Technical illustration has been a widely accepted form of communication. A technical illustration is an image such as a drawing or photograph that is used to simplify and describe a complex subject or process. These are detailed images that accompany a text or set of instructions in order to visually explain ideas, concepts, processes, and products. As Ross Maciejewski et al. explains:

> Often, an artist condenses the information to the most important details, creating a simple, clear, and meaningful image. The artist accomplishes this refinement by directing attention to relevant features, simplifying complex features, or exposed obscured features. This selective inclusion of detail provides levels of expression often not found in photographs. (62)

Even though early images were often rudimentary, drawings were an easy and natural way to communicate ideas. As time progressed, drawings became more detailed and accurate. For instance, many are familiar with the scientific works of Leonardo Da Vinci in the 15$^{th}$ century and the anatomical wax sculptures of the 17$^{th}$ century. World history is well stocked with these early technical illustrations and artists.

Historically, illustrators were required to have a knowledge and proficiency in traditional artist's materials. Even as illustrators engage technology in their studios, research continues to record the difficulties that technical illustrators are encountering. Humans have long used drawings to explain processes, ideas, and objects. However, it was not until the late eighteenth and middle of the nineteenth century when the field of technical illustration truly began to take shape as machinery became more widely available. According to Olivier Lavoisy, "During the eighteenth century, illustrations-drawings, engravings, colour-washes, sketches-were widely used in the technical field. From the end of the seventeenth century to the second half of the eighteenth century, presentations of the arts and trades were widely circulated in publications which employed a mixture of texts and drawings" (141).

These illustrations were a facet of communication and often the work of amateurs or fine artists. Louise Purbrick explains in "Ideologically Technical: Illustration, Automation and Spinning Cotton around the Middle of the Nineteenth Century" that "technical illustration was meant to enable the understanding of a mechanism once it was made, demonstrating how its parts connected and how it worked overall" (275). Before the nineteenth century, the field of technical illustration had not been defined as an individual profession. The inventor of the machine was responsible for all aspects of manufacturing including creating illustrations. Purbrick's article uses the process of spinning cotton to explain the industrial progression from manual labor to automation during the nineteenth century. She explains that at the time "millwrights maintained 'whole mechanical knowledge' which" was "comprised of three kinds of skills: the ability to theorize, to draw and to use tools" (Purbrick 281). According to Purbrick:

> The millwright could "handle the axe, the hammer and the plane with equal skill and precision; he could turn, bore, or forge with the ease and dispatch of one brought up to those trades...he was a fair arithmetician, knew something of geometry, levelling, and mensuration, and in some cases possessed a very competent knowledge of practical mathematics. He could calculate the velocities, strength, and power of machines: he could draw in plane and section. (281)

This type of “whole knowledge” approach gave birth to technical illustration in manufacturing, but it would eventually lead to a new field of work by trained and skilled individuals. The turning point in technical illustration came from the need to build and explain machinery. The possession of whole mechanical knowledge was soon divided into other professions when the division of labor and standardization became necessary. Purbrick states:

> Distancing drawing from using tools was important: it contributed to the formation of design as a discrete industrial practice and helped fix the hierarchy between conceptual and constructive work. It also created the conditions where standardization was essential. After the division of labour, knowing 'something of geometry', like the eighteenth-century millwright, and maybe mixing it in with personal reminders of measurements was no longer a viable method of making drawings for industrial use. Individual sign systems were meaningless when drawings were produced not for personal records but to transfer information between people or parts of the industrial process. (282)

This was also when “standardization was achieved through the implementation of the rules of geometry” (Purbrick 282). This established the rules for technical drawings and was the beginning of technical illustration education.

Scientific and medical illustration remain similar to their beginnings. Since these images are drawn from observation, scientific and medical illustration positions were and still are filled mostly by fine artists and a group of scientists that create illustrations to document their research. The greatest changes have been in the field of drafting due to industrialization. Louise Purbrick notes that it was not until the middle of the nineteenth century that “technical illustration became a conventional, popular form of representing machines” (275).

## Technical Illustration Education

In numerous kinds of communication, drafting, and design classrooms, computer technology has altered the educational environment and curriculum focus.  In “Exploring Perceptions and Attitudes Towards Teaching and Learning Manual Technical Drawing in a Digital Age,” Susan Valerie McLaren writes that while traditional drafting is still being taught in classrooms many educators are reluctant to continue that practice.  She adds, “some technology education teachers feel that they are involved in teaching a redundant subject. They believe that, in a world of CAD, there is no place for drawing boards and set squares” (McLaren 168).  Computer-aided design (CAD), programs were created to assist the illustrator with the creation and modification of design.  The belief that CAD programs are eliminating the need for traditional methods has led to many classrooms focusing more or entirely on digital media and has created a new problem within the field of drafting and design.  McLaren explains that “there are those in higher education and industry who are concerned about the poor standards of CAD drawings produced by engineering and design students, and workplace recruits” (168).  Her study suggests that CAD systems reduce the amount of skill required for effective drafting because they are “too easy to use” and reduce the student’s understanding of dimensionality.  McLaren states that learners who are taught traditional drafting methods have a better grasp on “moving from two dimensionally dominant interactions into three dimensions through the principles of drafting to interactive solid modeling” (169). She concluded that by beginning their education with traditional methods, the students have a better understanding of the “limitations, and the capabilities, of CAD systems” and spatial skills (169).

## Effects of Technology

Technology has given workers innumerable benefits within the workforce, but it has also led to many drawbacks for the skills required for technical illustration.  Chang-de Liu argues in “Negative Impact of Digital Technologies on Artists: A Case Study of Taiwanese Cartoonists and Illustrators,” that the use of technology is “deskilling” artists.  Liu has written other articles on the topic of deskilling, including how it affects journalism. From his studies he explains that technology streamlines the artistic process and by doing this it is "trivializing and simplifying tasks down to a low level, one that demands the least amount of skill" (Liu 457). Because of the deskilling effect "workers today are less skillful compared to the old generation of craftsmen who had full control over crafts production" (Liu 457). The process of deskilling occurs because technology allows the stages in a process to be "gradually converted into simple, repetitive tasks which can be performed by an operator with average levels of intelligence, education and dexterity" (Liu 457). According to Liu, technology has also created a demand for faster production of art and thereby reduces the quality of the product. He also notes the high costs of graphic design software and hardware, much of which is personally paid for by freelance or contract artists.

Rahinah Ibrahim and Farzad Pour Rahimian believe that CAD programs are also changing the creativity of illustrators. Ibrahim and Rahimian write in "Comparison of CAD and Manual Sketching Tools for Teaching Architectural Design," that "although current conventional CAD tools are advantageous for detailed engineering design articulation, they do hinder novice designers' creativity due to their intuitive ideation limitation" (978). However, unlike Liu, the authors list both the benefits and challenges presented by traditional drafting materials and current CAD tools. Throughout their study they observed students working with various CAD programs and recorded the students' experiences. Although Ibrahim and Rahimian cite the benefits of CAD programs, they do find areas where the programs are lacking in relation to traditional processes.

## Digital Media Versus Traditional Art

With the introduction of a new media such as CAD programs, technology has also changed the way art is stored and perceived. Adérito Fernandes Marcos defines and identifies the shift from traditional to digital media and the various challenges posed by this adjustment. Marcos explains that all art originates in the same way, but "digital art pieces differ from classical ones by the digital nature of their information content and supporting display material (canvas)" (98). While both traditional and digital art are created for the same purpose, the differences can lead to changes in the way the art is interpreted, interacted with, and stored. The study focuses on the Artech Initiative (Art and Technology Industries) that was founded to promote a community of digital artists through activities about digital art. Marcos identified the problem that many digital artists face; the lack of a "common design space where digital artists can smoothly progress from the concept/idea to the final product" (99). Through his study, Marcos acknowledges that digital art "faces a number of unprecedented challenges…because of the characteristics of the medium itself in presentation, collection, and preservation. Digital art often requires user engagement, which can be highly volatile when its message (content) is not understandable at a glance" (99). The interactivity of digital art contrasts with the way traditional art is perceived because traditional art is seen as a more static medium where the user is merely a spectator. Digital art also creates new challenges "because of the pervasive characteristics of the digital medium and the continual software and hardware development" (Marcos 99). Since technology is continually developing, every aspect of digital art is dynamic. New hardware allows for new techniques and applications. New software creates new environments for creation and format. The constant growth that digital art experiences differs greatly from the physical, fixed media in traditional art. While digital art sees constant transformation, very little change has occurred in the tools and techniques used in traditional media. The continual evolution of digital media is not always beneficial. Marcos suggests that technology's advances "makes digital art, in general, unstable and difficult to deal with" (99). The difficulties posed by digital media create new challenges and alters the role of the technical illustrator.

## Changes in the Technical Illustrator's Role

Digital media have created new hurdles for illustrators, but they have also broadened their possibilities. As Joe Nicholls and Robin Williams point out in their article, "The Changing Role of the Medical Illustrator," this media has the potential to propel illustration to new roles within their fields. The challenges brought on by technology can be transformed into new opportunities in areas such as telemedicine and instruction. Their article focuses on how medical illustrators have not realized the "extent to which new technology offers the opportunity to make a much more profound contribution to the provision of healthcare and the way healthcare practitioners are taught" (Morton, Nicholls, and Williams 67). These opportunities will alter the role of technical illustrators, creating new outlets for their work and new demands. Technology has offered technical illustrators a broad set of new tools including unlimited storage, a vast palette and toolset, and new opportunities within their field. However, as seen in this literature review, there is still some debate about the effects of technology on skill, education, and the need for traditional methods. As new illustrators enter the field, the future of technical illustration depends on how these and other issues are resolved.

## Main Perspectives Drawn By Technical Illustrators

As in any art-form, there are different types of illustrations that are used for different purposes. Specific perspectives and angles are used in technical illustrations to provide an accurate and helpful depiction of the subject. The perspective used depends on its implementation and the audience's needs. There are six main perspectives that technical illustrators draw. These include the cutaway, phantom view, exploded view, step-by-step, info-graphics, and animations. I provide a brief overview of each of these perspectives.

The cutaway is an image where the exterior of the subject is cut to reveal the interior (see fig. 1). According to J. Diepstraten, D. Weiskopf, and T. Ertl, "cutaway drawings in technical illustrations allow the user to view the interior of a solid opaque object" (523). This allows the user to see inner elements and processes that might not be visible otherwise. Choosing the cutaway illustration avoids "ambiguities with respect to spatial ordering, provide a sharp contrast between foreground and background objects, and facilitate a good understanding of spatial ordering" (Diepstraten, Weiskopf, and Ertl 523). Cutaway images are popular in many fields such as science and medicine, production and manufacturing, and advertising.

Figure 1: Cutaway view illustration of an animal cell.

Source: Cindy M. Caudill

The phantom view, or ghosted view, makes one part of the image transparent in order to display other aspects that might be hidden (see fig. 2). This is similar to the effect that a cutaway image provides. However, instead of cutting out a piece that is in the way, the illustrator hides that part of the image. This is achieved by lightly drawing in the object, but leaving that section see-through and without detail. The outcome is similar to an x-ray vision effect. The phantom view is used for many of the same purposes as the cutaway.

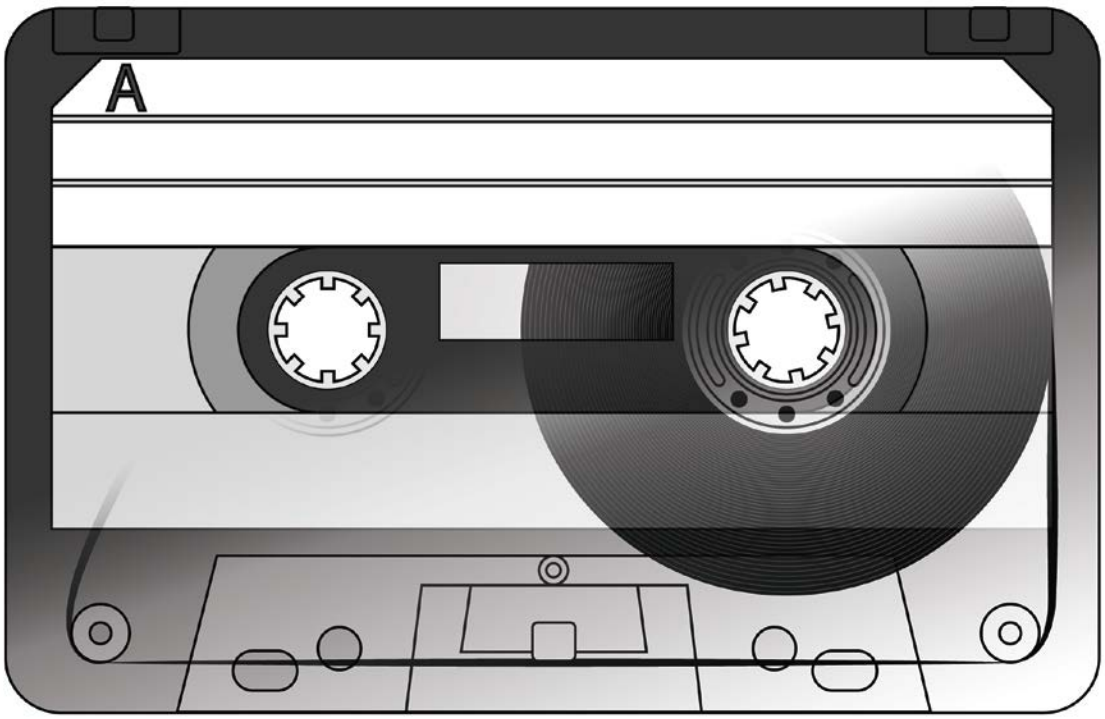


Figure 2: Phantom view illustration of a cassette tape.

Source: Cindy M. Caudill

The exploded view, also called illustrated parts breakdown (IPB), shows an object with all of the pieces pulled apart (see fig. 3). When applying the exploded view to instructions, John M. Penrose states that they "show how parts combine to form a whole" (22). This is useful to show all of the components, where they connect, and to give a visualization with little or no words. The exploded view is used primarily for construction purposes when it is necessary to show where parts fit into a whole.

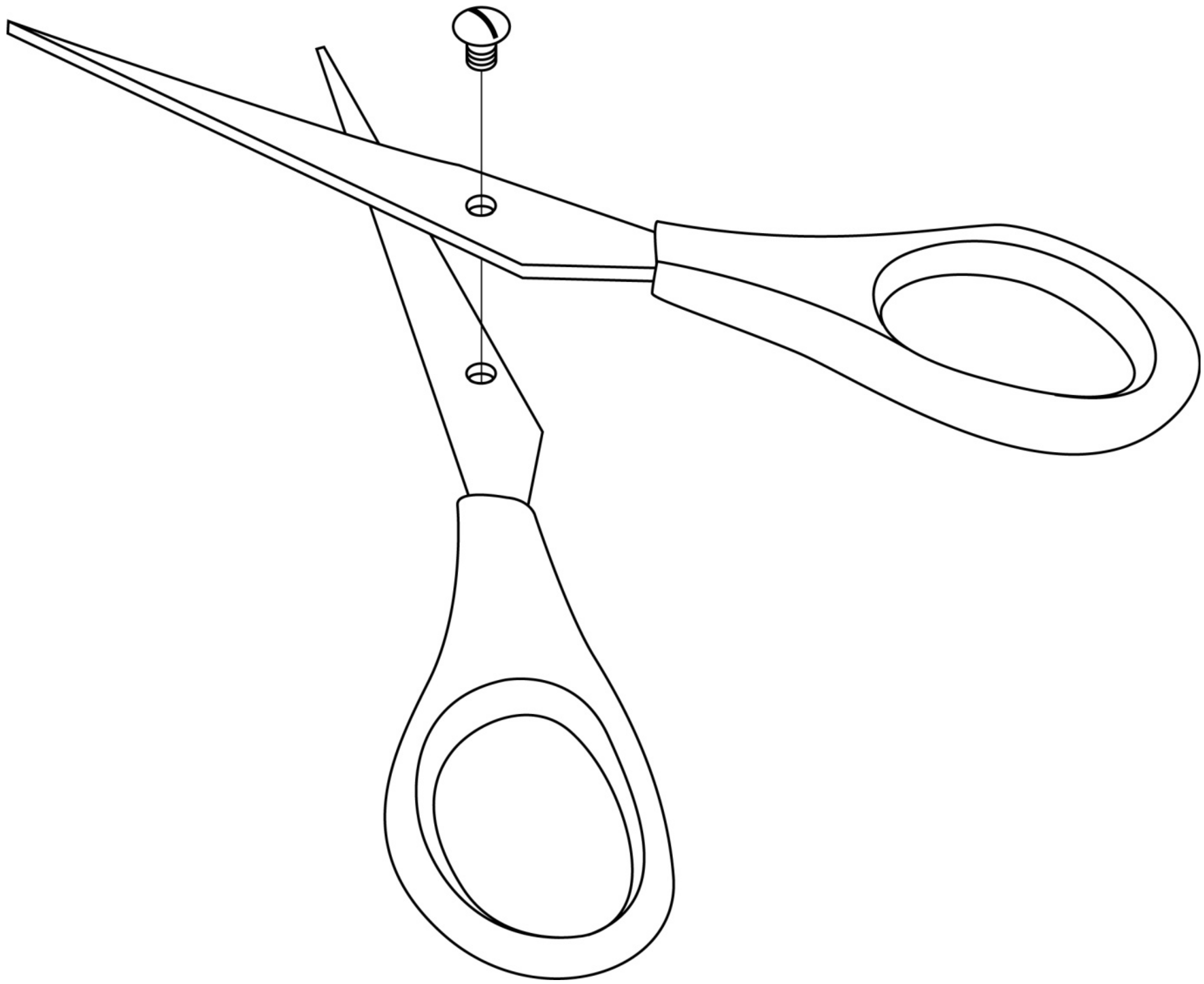

Figure 3: Exploded view illustration of scissors.

Source: Cindy M. Caudill

The step-by-step view uses separate images to illustrate a set of instructions (see fig. 4). These drawings are typically sequential with each one building on the previous. Step-by-step drawings can be useful in accompanying text or standing alone and are often included to explain a process.

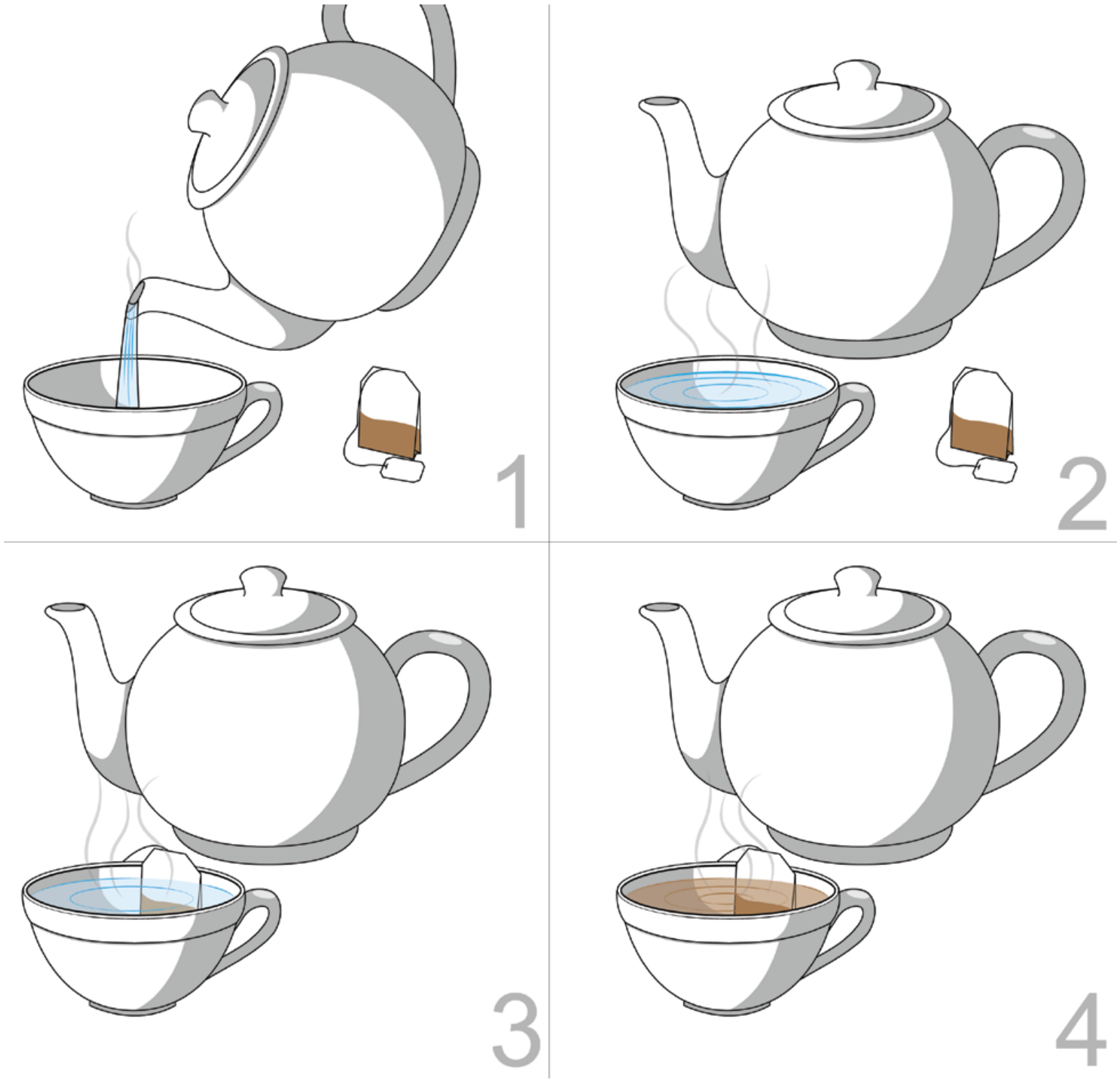


Figure 4: Step-by-step graphic illustrating the process of making tea.

Source: Cindy M. Caudill

Info-graphics, or informational graphics, are used to display data such as charts or graphs (see fig. 5). These are typically low-detailed and serve a specific purpose. The design is centered on offering information in a quick, easy to read manner. Info-graphics are common on brochures and manuals where percentages or statistics are being displayed.

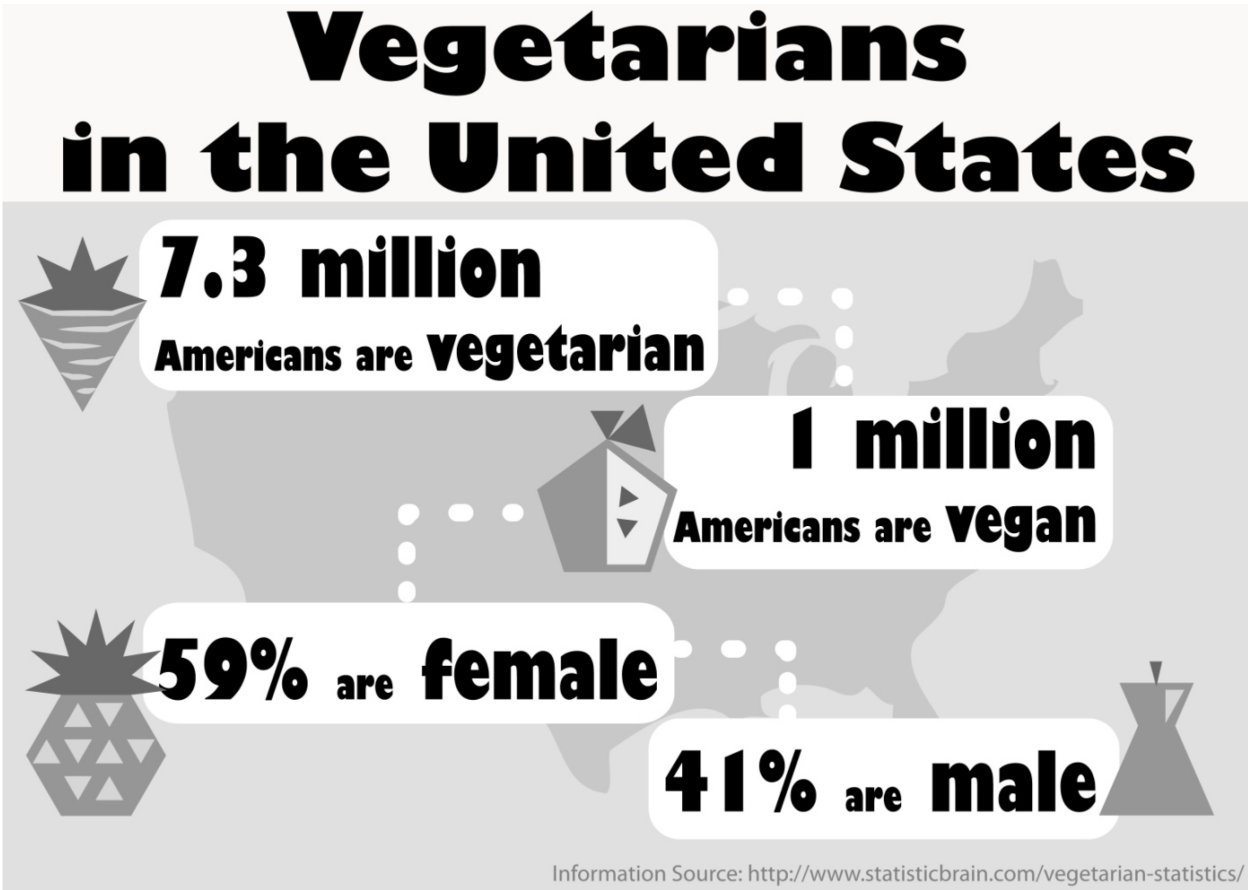


Figure 5: Infographic displaying the statistics of vegetarians in the United States.

Source: Cindy M. Caudill

The most recent addition to the illustrator's set of choices is animation. With the help of technology, technical illustrators are now able to work in 2-dimensions or 3-dimensions and with motion. Animations can be created in high or low resolutions, allowing the artist to determine the amount of detail that is necessary. This is most helpful when explaining movements and processes. Animations are often sold with products as instructional videos or software. Many companies also upload these animations to their website for global access.

These six views are illustrated from various angles such as isometric, orthographic, and perspective. Isometric drawings are situated at 30 degree angles and are common in manuals (see fig. 6). The isometric drawing is most often used when measurements need to be exact. Dennis Szymanski states that "drawings of this type are often used for patent drawings, exploded views, assembly drawings and architectural renderings" (22).

Figure 6: Isometric illustration of an e-reader.

Source: Cindy M. Caudill

Orthographic images are straight-on angles drawn from the front, top, or side (see fig. 7). This allows the viewer to see only one side of the object at a time. Orthographic images are used when it is not necessary to display dimension or to help construct an isometric image.

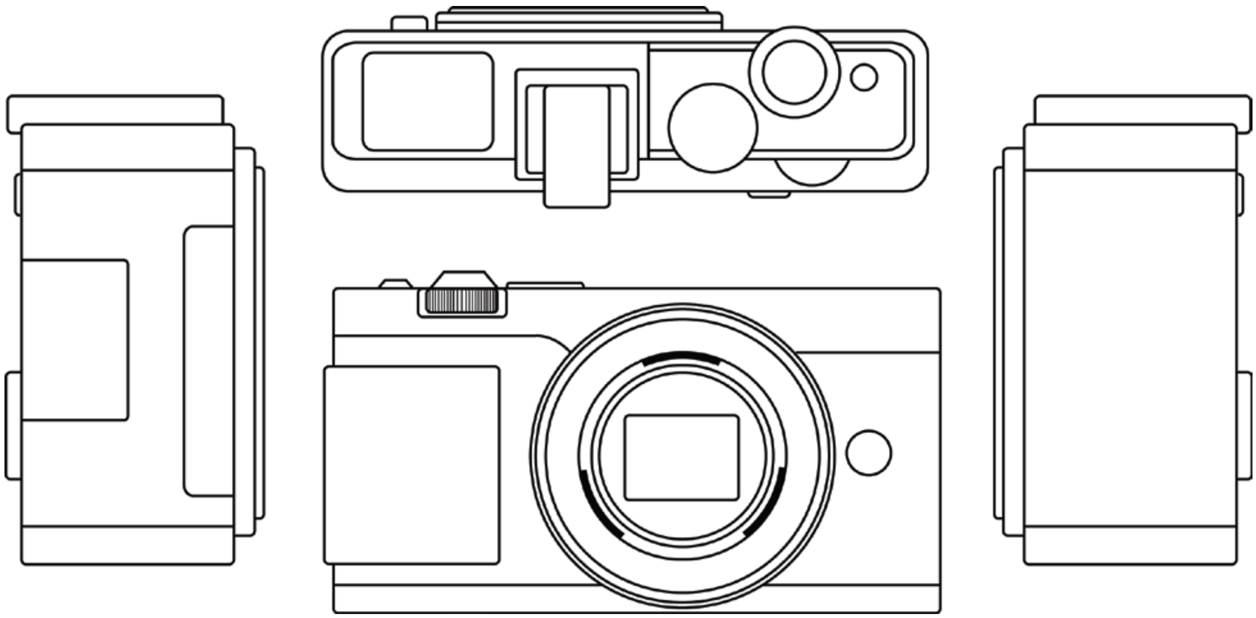

Figure 7: Orthographic illustration of a camera.

Source: Cindy M. Caudill

The perspective angle is the most common type of illustration because it is the most realistic and allows the image to be drawn from the user's perspective (see fig. 8). According to Szymanski, "perspective drawing relies on sizes diminishing as they appear to recede" (22).

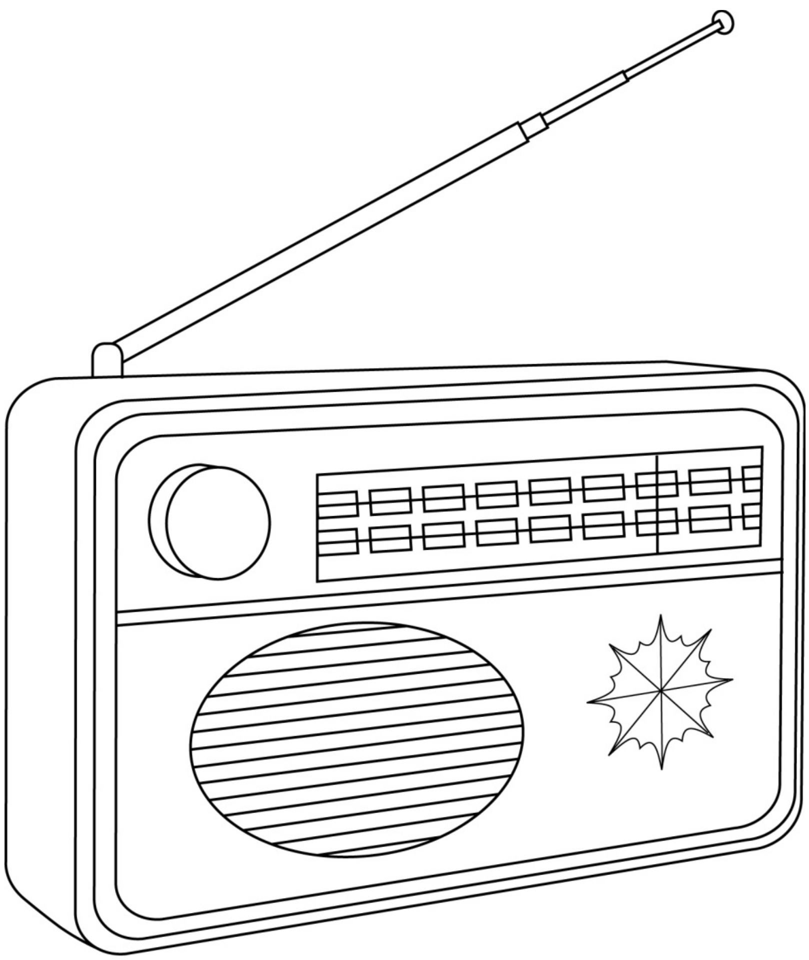

Figure 8: Illustration of a radio in perspective.

Source: Cindy M. Caudill

The variations in technical illustrations are dependent on the subject. The view and angle is chosen based on the purpose of the illustration. For example, illustrations for installing hardware in a computer tower might be drawn as a phantom view from the perspective angle. This allows the user to see the computer tower and corresponding parts as they would in a real situation. The variations in illustrations not only include the view and angle at which they are drawn, but also the technique and color. Exploded views are typically black and white line drawings. However, some images require shading to show lighting and depth while others use a technique called stippling. Stippling gives the same effect as shading, except instead of a smooth gradient the shading is made from tiny dots applied to the image. Stippling produces a black and white image and is widely used in scientific illustration. Color is applied to some images through the use of various mediums such as watercolor paints, color pencils, and graphic design software.

## Types of Technical Illustrators

Technical illustration can be viewed as an interdisciplinary subject since it is a combination of fields such as technology, art, and communication. Technical illustration is also employed by a variety of fields. Technical illustrators are trained and hired to create drawings, info graphics, diagrams and blueprints for a multitude of subjects including science, medicine, and engineering. Scientific illustration, medical illustration, and drafting are three subfields within technical illustration. Each requires specific tools and training to produce images that reflect their needs.

Scientific illustration focuses on plant and animal life and is widely used for educational and research purposes. Elaine R. S. Hodges explains that “scientific illustration is the accurate depiction of objects and concepts in the biological and physical science” (104). This type of accuracy is needed “to communicate research results and concepts” (Hodges 104). Most students are familiar with the cutaway illustration of the parts of a cell or an animation of the water cycle. Images such as these are most often found in textbooks and on charts. There are various routes to becoming a scientific illustrator. Some scientific illustrators possess an associates or bachelor’s degree in scientific illustration while others have an interdisciplinary background in the arts and sciences. Another option is to obtain a certificate in scientific illustration through an accredited program. Each of these options requires both the knowledge of science and the skill to create detailed, accurate images.

Often the fields of medical and scientific illustration overlap, but the training and employment can be very different. Medical illustrations are depictions of anatomy and physiology, pharmacology, and surgical procedures. For example, a medical illustrator might draw the muscles surrounding the eye or a cutaway of the heart displaying certain valves and functions. Illustrations such as these are needed for research and educational purposes. In the article, Morton, Nicholls, and Williams explain that “medical illustrators are generalists who through the process of illustration, in its broadest sense, can help to make the communication process between subject expert and student, or between one specialist and another, as effective as possible” (65). The field of medical illustration began with training in medical photography, but has expanded rapidly and today the job typically requires a graduate degree that includes extensive coursework in the arts and medicine.

The fields of scientific and medical illustration are very similar. Both require an attention to detail, patience, and creativity. Some drawings are done from observation such as sketching a specimen. Other drawings require the illustrator to think creatively. This occurs when the subject is complicated in nature or might be concealed. For instance, in order to depict the ecology of a pond, the illustrator might create a cutaway of the land that shows the various layers of the water and surrounding soil in order to show the respective inhabitants and plant life.

The field of drafting is significantly different from scientific and medical illustration. Drafting is used to show processes, functions, assembly, and layouts. The most common need for drafting occurs in the field of engineering. Drafting also involves a different set of tools, techniques, and training. Drafters possess artistic skill as well as spatial recognition, and a background in mathematics. They often have degrees in computer drafting and design or engineering. Technical drawings are frequently drawn from cutaway, exploded, and step-by-step views. This reflects their use in manufacturing and instruction. These well-established fields have relied on images to illustrate new ideas and educate users on difficult concepts. From the beginning of society, the need to explain concepts has been an essential part of communication.

# CHAPTER 2: TRADITIONAL AND DIGITAL METHODS

The methods used by technical illustrators typically depend on the field of employment. Scientific and medical illustrators use a different set of skills and techniques than draftsmen. They also require a different set of tools. Traditional materials needed by scientific and medical illustrators are similar to those used by fine artists. Traditional drafting materials are specific to the line of work to meet the needs of the draftsman. It is important to understand the types of tools and techniques traditional illustrators use and how that affects the appearance of a finished image. Traditional tools create a style and aesthetic that is distinctly different than that produced by digital tools. Digital images have a more polished appearance, whereas traditional illustration methods can appear grainier due to the texture of the materials.

Although digital and traditional materials differ in use and outcome, both are capable of producing quality images that suit the needs of the illustrator. Scientific and medical illustration primarily involves drawing a detailed, accurate subject from observation. This gives the illustrator some degree of artistic expression in color choice, perspective, and media selection. Drafting is a very precise form of technical illustration and requires accurate measurements. Although the fields of scientific and medical illustration differ from drafting, they must all maintain a sense of realism, proportion, and attention to detail when creating the images. The purpose of this chapter is to discuss and contrast the tools, techniques, and the illustration process used by traditional and digital illustrators and to provide the benefits and difficulties of both methods.

## Traditional Scientific and Medical Illustration Tools

The supplies needed for scientific and medical illustration are generally comprised of fine art materials and require comparable skills and techniques to properly employ. Traditional illustrative methods include pen and ink, pencil, colored pencil, watercolor, and carbon dust. These can be used separately or together creating mixed media artwork. As Elia T. Ben-Ari explains in her article, "Botanical Artists Blend Science and Aesthetics," "the most commonly used medium for botanical artworks that are not intended for use in scientific publications is watercolor, in part because the paint dries quickly" (4). Many other illustrations such as "beautiful botanical paintings and illustrations are also made using gouache, pencil, acrylic and oil paints, and even woodcuts. And, as in the case of scientific illustrations of plants, realism, attention to detail, and clarity (the "readability" of the subject) are important in botanical art created primarily for aesthetic purposes" (Ben-Ari 4). Since the only method of archival and reproduction of traditional illustrations is through scanning, scientific and medical illustrators must consider the quality and durability of the tools.

Numerous kinds of pens and pencils are available on the market. Artists typically choose drawing pens that contain archival ink; a waterproof and fade-resistant ink that allows for a longer lasting artwork. These pens also provide smooth ink that does not smudge. Drawing pens can have tips as small as 0.05 mm and can be bought in a variety of colors. Pencils come in a variety of grades. The scale is based on hardness (H) and blackness (B) and range from 6H, the lightest, to 8B, the darkest. Harder graphite pencils produce a lighter drawing while blacker pencils produce a darker drawing.

Like graphite pencils, colored pencils also have varying hardness. Hardness depends on the type of lead that the pencil contains which can be wax-based or oil-based. Colored pencils come in a variety of colors with some brands packaging 120 colors in a set. Similar to the archival ink in pens, illustrators often choose colored pencils that are lightfast, or do not fade, to guarantee the brightest, longest lasting work of art.

Watercolor paints are often used in conjunction with pens, pencils, and colored pencils. This is done to add detail to the watercolor image after the paint has dried. The quality of a watercolor paint depends on the source of the pigment that is used. Some paints are earth-based and contain pigments found in nature while others are synthetic. Since scientific and medical illustrations will be archived, the artist might look for watercolor paints that will last the longest. Fugitive paints fade, while non-fugitive paints resist fading.

Carbon dust is distinct because of its application. Carbon dust became a popular medium in medical illustration because of its even appearance. By using an ermine brush, the illustrator can apply layers, each one building and darkening the previous layer, to produce a smooth, consistent gradient similar to an airbrushing effect.

## The Traditional Illustration Process

Scientific and medical illustrators often begin by thoroughly studying their subject. Observation can be done through physical examination or through photographs. In order to capture details, the technical illustrator might use a microscope to closely examine details of the specimen. Then the illustrator begins drawing preliminary sketches. These sketches are typically black and white, pencil drawings. The drawings are either completed as a whole image or in separate parts. These sketches are then redrawn on archival paper as a final image. In order to ensure a clean transfer the illustrator might use a projector or tracing paper. Duplicating image also helps the artist maintain symmetry and accuracy. After the final image has been drawn, the illustrator can then begin applying details, shading, and color. "Another convention has to do with when and how to drop out lines or show a break in the drawing. For example, if the artist decides not to show a particular leaf, she must indicate the omission in some way, such as by sketching in the base of the leaf. The amount of shading in scientific illustrations is kept to a relative minimum so as not to obscure the characters" of the subject (Ben-Ari 3). These and other decisions help blend the worlds of scientific accuracy and artistic presentation.

The illustrator may choose from varying techniques to depict the image. These techniques are dependent on the medium that the illustrator has chosen to complete the image. As Ben-Ari explains:

> Scientific illustrations are most often done in black and white, usually with pen and ink or brush and ink. Half-tone drawings, which are more costly to print, may be used to give a better indication of mass and color. Scientific illustrators rarely use color, mainly because of the economics of printing, but also because adding color may obscure the essential "characters" of the plant, such as the pattern of veins in the leaves or the way in which the stamens are attached in the flower. (3)

Within the technical illustration field, a popular technique used in pen and ink drawings is stippling. Maciejewski et al. explain that "in stippling, the artist places dots on a surface of contrasting color to obtain subtle shifts in value. These dots can vary in size, volume, and arrangement to create the illusion of different texture, tone, and shape" (62). These dots give stippling “its ability to depict tonal variations, stippling is well suited for illustration objects with fine detail, subtle texture, and small changes in shading" (Maciejewski et al. 64). Although there are other techniques used in technical illustration, stippling has long been established as a traditional style for black and white illustrations because it allows the illustrator to depict details.

## Traditional Drafting Tools

A draftsman’s work requires a high degree of mathematics and the skills necessary for rendering detailed, reproducible work for industries like manufacturing and architecture. Because of the nature of the work, the draftsman’s toolbox is filled with a variety of instruments for measuring length and angles as well as some traditional drawing utensils. Traditional methods of drafting employ tools like a drafting board, T-square, triangle, drafting scales, an eraser and eraser shield, and an assortment of pens and pencils for drawing lines of varying thicknesses.

The drafting board, or drawing board, is a smooth, rectangular surface that serves as the illustrator’s workplace. Drafting boards come in a variety of sizes. The size of the board is chosen in relation to the size of the paper that the draftsman most often uses. Drafting paper ranges in size from 24”x36” to 36”x48”. An illustrator can also choose form a portable drafting board or a drafting table. Both offer the illustrator a clean, even working station. The T-square is rested on top of the drafting board and is used to measure and draw horizontal lines. T-squares are available in different lengths and materials. The T-square length is chosen in relation to the size of the drafting board. The triangle rests above the T-square and is used to measure angles and draw vertical and angled lines. There are two triangles used for drafting. Each triangle has straight edges that measure in millimeters and corresponding angled sides. One triangle has angles that measure 45˚, 45˚, 90˚ and the other triangle measures 30˚, 60˚, 90˚. Drafting scales are used to measure lines, not draw them. The architect’s scale is three sided and is used to gather measurements of the drawing. The engineer’s scale is also three sided, but is more precise and is used to measure lengths. Although both come in a variety of lengths, the most commonly used is 12 inches. The eraser shield is used with the eraser to erase small areas while preserving important parts. It is a small, lightweight, metallic sheet that has openings of different shapes and sizes. This tool is ideal for drafting because it allows for erasing specific areas without smudging or erasing other parts of the drawing.

The type of pen or pencil used depends on the line weight and intensity that is needed. In order to distinguish certain areas of a drawing, draftsmen will choose lighter and darker pencils or pens with varying thicknesses. Many illustrators also choose to use technical pens. Technical pens also allow for smooth, consistent lines and either contain a replaceable ink cartridge or have a refillable ink reservoir.

Depending on the type of drafting, other supplies might be needed. For instance, architects use adjustable triangles, French curves, and both engineering and architectural drafting scales as well as lettering triangles, lettering guides, and letter templates. Landscape architects routinely use circle templates to outline tree circles. This tool is easier to use than a compass and comes in a variety of sizes. It is also common for landscape architects to use a thick marker to define the outline of structures in their drawing or to add shadowing. Some technical illustrators create three-dimensional models and need tools such as utility and craft knives and glue.

## Traditional Drafting Process

The process of drafting begins with putting the paper on top of the drafting board and aligning it with the bottom edge of the board. Then the paper is held in place with board clips. Afterwards, the T-square is placed on the drafting board. The short side of the T-square is aligned with either the right or left side of the drafting board depending on whether the illustrator is right or left handed. Placement of the T-square's short side is opposite of the drawing hand. The triangle is placed above the T-square. Then the edge of the triangle is used as a measuring guide to determine where and how long the line will be drawn. The technical illustrator will then use these and other tools special to their fields to measure and complete the image.

## Benefits and Difficulties of Traditional Illustration and Drafting Methods

The traditional tools for scientific and medical illustration are readily available and can be purchased at varying cost. An illustrator can purchase most of these materials at a moderate price, but has the option of buying cheaper or more expensive supplies. Although drawings can be completed with low-end materials, higher-priced supplies often offer greater control, reliability, and produce a longer lasting, more aesthetically pleasing image. Drafting tools can also be purchased at a moderate cost. Many of the items such as the drafting board, T-square, and triangle do not need replacement often. However, it is necessary to purchase new pens, pencils, and paper. The greatest drawback to using traditional illustration and drafting tools is the cost over time. As drawings are completed, supplies will need to be replaced.

According to Ibrahim and Rahimian, manual sketching tools offer “flexibility in ideation” (980). The authors believe that this is true because of the “tangible interface” that traditional methods offer the illustrator. Many artists agree that the tactile and physical feedback offered by traditional media allows for more control, freedom, and manipulation. This gives the illustrator more artistic expression and the options to physically determine line weight and shading. Traditional tools are considered easier to learn and use and they offer more "accuracy and clearness" (Ibrahim and Rahimian 980).

However, creating an image using traditional tools requires patience and attention to detail and the fragility can create difficulties. Traditional drawings are more permanent and mistakes are not easily remedied. A participant in Tracey Bowen's study described traditional drawing:

> Physically drawing is a lot less forgiving than being on the computer. You can erase things so quickly on the computer. Drawing on the computer is totally different for me than drawing with pen or pencil or painting. If I'm painting and I don't like what I'm painting, I have to put it aside and come back to it maybe two days to three days later depending on what medium I'm using. But with the computer, you can sit there for ten hours, and work faster because you can erase things immediately and go over the top of things and layer and take it away if you don't like it. (226)

Upon editing or duplicating an image there is "difficulty in transition of the format when being used in other design stages" (Ibrahim and Rahimian 980). With traditional materials there is also a "lower capability for shifting from micro to macro level and vice versa" (Ibrahim and Rahimian 980). Traditional drawings provide "lower details of visualization" (Ibrahim and Rahimian 980).

## Digital Art as a Medium

Digital art, or new media, has only recently been recognized as an art form. According to Sherry Mayo, "new media began in the late 1960s with computer-assisted design (CAD) programs that were implemented in building engineering" (101). This type of technology and that used for military purposes soon "became a tool of expression in the hands of artists" (Mayo 101). Marcos stated that "digital art, as it is now known, entered the art world in the late 1990s when museums and art galleries (finally) started to incorporate digital art installations and artifacts in their exhibitions and support initiatives in this field" (98). Out of this recognition grew new possibilities of expression and interpretation for artists in all fields including the "development of image manipulation, real-time interactivity, 3D animation, and immersive simulation environments has been the focus of computer graphics for more than forty years" (Mayo 101). According to Courtney Bryant, "the computer is simply the most recent addition to an artist's tool chest of media necessary for a display of technical skill" (44). With the integration of new technologies, "the digital medium witnessed extraordinarily accelerated technological developments in the 1990s, a period usually referred to as the 'digital revolution'" (Marcos 98). Even though "the foundations of many digital technologies and digital art experiments had been formed up to 60 years earlier, digital technologies have become ostensibly ubiquitous and highly expressive over the last 15 years" (Marcos 98).

Although digital art has become increasingly popular among artists, there are still challenges that face illustrators. These challenges are spawn from "the characteristics of the medium itself in presentation, collection, and preservation" (Marcos 99). This is also due in part to the artist's unfamiliarity with the digital environment, conflicts in education, and the learning curve of new software. Technical illustrators previously worked with traditional materials in a traditional studio environment. Current illustrators are now working with digital tools that do not require the same physical dexterity or coordination and that does not respond tactilely or visually as traditional media does in a traditional environment. Many of the rules and techniques associated with creating traditional artwork are not necessary in a digital world. The traditional technical illustrator is used to the workplace as well as the freedoms and restraints associated with traditional media. When creating digital art, the illustrator has to learn and adjust to his or her materials and work confined to a screen. Even the process of drawing a line changes when digitized. A traditional artist selects paper based on size and texture and then chooses a writing utensil with the desired medium, size, and color. The artist decides on the line thickness, smoothness, and density by applying pressure while drawing. In contrast, a digital artist must create a new document with settings that vary in size, resolution, and format. Then he or she must select a tool from the toolbar, define the tip shape and size, apply a smoothness, texture, or desired effect, as well as choose the hardness and spacing among other options. The digital toolbox was created to mimic the traditional toolbox, but it comes with a plethora of options and customizability that is foreign to a traditional artist.

## Digital Illustration and Drafting Tools

In order to create a digital drawing, the illustrator needs a computer, graphics tablet, and the proper software. Although the tool list is shorter, these items are purchased at a much higher price than traditional materials. The illustrator's computer must meet the specifications required by the graphics software. Often this means installing more random access memory (RAM) and a higher-end graphics card.

Many graphics tablets are available to choose from that range in price, size, and specifications. Tablets range in size from 4" x 5" footprint to a 21" LCD screen. Lower-priced graphics tablets have a footprint that is the rectangular surface area for drawing. These can be as small as 4" x 5" and have a relatively low purchase-price. The user draws on the surface with a pen, but looks at the monitor. This is very similar to using a mouse, but offers the feel of drawing by hand. Higher-end graphics tablets are large, LCD monitors that can be drawn on directly with the pen. These are often much higher priced, but they eliminate the monitor and allow the illustrator to see the image on the surface that they are drawing.

When purchasing a tablet, there is also the question as to what type of pen and the sensitivity of the tablet. Some graphics tablet pens require batteries, replacement nibs, or are tethered to the tablet. These are all considerations that must be taken when selecting a tablet. There is also the question of sensitivity. Higher sensitivity levels translate into a smoother and more responsive drawing experience.

Some illustrators find it easier to work with dual monitors because it offers more space for reference photos, notes, and the ability to switch between programs with ease. The type of software required depends on the type of drawing that will be produced. Scientific and medical illustrators often use typical graphic design software. These can range in price depending on their capabilities. There are programs for drafting, photo editing, illustrating, digital painting, and animation. Some software companies offer bundled software, or suites, that suit the needs of a particular field. For instance, some software suites are aimed at technical illustration while others are for video editing.

## Digital Scientific and Medical Illustration Methods

Digital scientific and medical illustration requires similar tools that as a graphic designer. In order to draw in a digital environment the illustrator needs a computer, graphics tablet, and illustration software. In order to smoothly run graphics software, it is essential to own an updated computer with the necessary drivers needed for the graphics tablet.

Graphics tablets are composed of two main parts: the tablet's pad and a stylus. The illustrator uses the stylus to draw images on the pad. The stylus, or pen, is a shaped like an ordinary writing utensil, except that the tip is plastic or rubbery and does not wear easily. Some pens come equipped with buttons and an eraser tip. The buttons can be customized for shortcuts to minimize switching between the pen, mouse, and keyboard. The eraser tip is similar to the pen's tip except that it allows the illustrator to flip the pen over and digitally erase content, just as a real pencil functions. The pen is applied to the surface of the pad which is pressure or touch sensitive. Graphics tablets come in a variety of sensitivities and sizes. The sensitivity of the tablet is available in levels like 256 and 2056. Higher sensitivity levels create a more responsive tablet and increases the range of shading, line thickness, and control. Greater sensitivity allows user to have the same tactile experience with a graphics pen and tablet as with traditional pen and paper. While casual users might benefit from a small tablet such as 3”x4”, professional illustrators often opt for a larger surface that allows the user to work in a more realistic area. Some graphics tablets are flat, matte surfaces with shortcut buttons, while others are similar to touch screens. Touch screen models are preferred because the user sees the image on the surface that they are drawing, much like drawing on paper.

In order to draw with the graphics tablet, the user must have illustration software installed on his or her computer. Technical illustrators typically use the same software as graphic designers. The two categories of illustration software is raster-based or vector-based. Raster-based programs are used primarily for digital painting. This type of software allows the user to paint or draw as he or she would with traditional materials. Raster-based programs typically offer a range of tools and a diverse palette. Tools included in this type of software include a brush, pencil, eraser, text input, color selector, shapes, and dozens of others. In Marie Altenburg's article, "The Digital Artist Within Us," she notes that digital painting programs also offer "a list of mixer brushes, including several natural media brushes. Like true artists' brushes, they come in an array of styles including various types of round, flat, and fan brushes" (19). These and other tools are easily customized to suit the needs of the illustrator. For instance, the user can choose the size, shape, opacity, texture, color, and numerous other options. Using these tools the illustrator is able to draw, paint, and sketch freely to create the desired image.

Vector-based software uses geometry to create points, lines, curves, and shapes. These programs come equipped with many of the same tools as raster-based software. The biggest differences are the way an artwork is created and the final product. The user can freely draw using the tablet. When this occurs, the program will create a fillable shape based on the user's strokes. Another method is to create an image point by point, specifying each curve and angle to produce the shape. These shapes can be layered one of top of the other to add details to the image. Although raster-based software produces images that are more similar to paintings and drawings, raster images are not easily resized. They can be made smaller, but cannot be enlarged without experiencing pixilation. Vector-based images are more versatile and can be infinitely resized; larger or smaller.

## The Digital Scientific and Medical Illustration Process

The digital illustration process is similar to traditional illustration. The main difference is that illustration software allows the user to work with layers. Layers are transparent and build on top of the previous with the first layer being at the bottom. When starting a digital illustration, the illustrator creates a rough sketch on layer one. Then on layer two, the illustrator will finalize an outline of the image. The remaining layers will hold details and colors. Altenburg explains that during the digital painting process many artists "also add additional layers before they begin or even after working on a painting. These layers could be hue/saturation adjustment layers or filter layers. Changing the blending modes of these layers also changes their appearance" (Altenburg 20).The illustrator can create and delete layers, rearrange and merge them. Mistakes can be easily remedied with the “undo” function and content can be easily copied.

Sometimes an illustrator will draw the outline of an image with traditional materials and then scan the image. Once the drawing has been scanned, it can be manipulated with the illustration software. This gives the illustrator freedom to experiment, duplicate, and erase the content with ease. This method is also useful when the art will be needed in a digital format for printing or electronic distribution. While most digital illustrations are noticeably different in style than traditional drawings, Maciejewski explains the traditional methods implemented by graphic artists:

> Computer graphics artists have adopted many traditional illustration techniques in nonphotorealistic rendering (NPR). They have particularly focused on traditional pen-and-ink techniques, attempting to mimic artists' strokes, textures, and tones through the placement of lines and points of varying thickness and density in computer-generated images. (62)

Although this approach produces unique artwork, the study by Maciejewski et al. concludes that "the discrepancies between hand-drawn and computer-generated texture statistics show that there is still room for improvement in computer-generated stipple textures. In the small sample we analyzed, hand-drawn texture statistics seem to have a higher correlation to real textures" (73).

The artist working as an individual has also been challenged by technology. Ernest Edmonds and Linda Candy have identified a shift in the creative process in their article, “Creativity, Art Practice, and Knowledge.” The authors observed that “since the mid- 1960s, artists have been actively and successfully using digital technology in their practice, with many of these artists classified as "computer experts." Bringing this expertise of art and technology together has usually been the achievement of one person working alone. As we consider more recent digital art, increasing collaboration occurs between people from different disciplines with different skills. The paradigm for digital art seems to be shifting toward collaborative practice as a norm" (Edmonds and Candy 91).

## Digital Drafting Tools

The tools most unique to digital drafting are computer-aided design (CAD) programs. CAD programs are specific to the field of drafting. They allow the user to create accurate, scaled drawings in either two or three dimensions. The drafter first chooses 2D or 3D software for the project. Once the need has been determined, the drafter can then begin working on the digital canvas. In 2D drafting software, the illustrator views the project from a top-down perspective and can either work by a point-and-click method or by entering coordinates for the creation of lines and shapes. In 3D software the drafter can choose which view to begin working such as the top, bottom, side, or from a custom perspective. The drawing process is then similar to working with 2D software. All lines and shapes are created by clicking on the screen with a mouse or by entering coordinates. The greatest difference between 2D and 3D software is that three-dimensional software allows the artist to work in the x, y, and z planes. Ibrahim and Rahimian explain the changes that occurred with the introduction of computers:

> Gratitude to manual sketching methodologies started waning with improvements of Computer Aided Design (CAD) tools and their increasing utilization in complex projects due to globalization challenges. A more important reason for this tendency towards

> digitization of a design process is the added value of digital representation for future analysis and process integration. (979)

Illustrators began noticing the advantages that CAD software offered and began migrating toward digital methods to use the new technologies.

## Benefits and Difficulties of Digital Methods

Digital illustration offers many benefits and drawbacks. Graphics tablets and software provide the illustrator with opportunities and freedom that traditional materials lack. Digital supplies are initially expensive to purchase, some costing fifty times the price of traditional materials, but they do not need replacing as often. To curb the price of updating and purchasing software, the newest option in software is the cloud subscription. Instead of purchasing the programs, users can pay a monthly fee to use the newest version of the software. Cloud subscriptions can save illustrators money by eliminating the need for updates. However, it is not always necessary to have the latest version so the subscription service can be costlier in the long run.

The digital artist's toolbox has been created to mimic that of the traditional artist. Within the illustration programs there are digital equivalents to pens, pencils, watercolor brushes, colored pencils, markers, and acrylic paints. With the proper knowledge of the program, many digital illustrators possess the skill to properly implement these options to create images that appear traditionally drawn. However, there are some techniques that computers have not been able to recreate. This includes realistic stippling to produce details and shading as well as the grain of paper and layering of watercolor paint.

CAD software offers many benefits to the illustrator. As noted by Ibrahim and Rahimian, drafting software gives illustrators the "capability for zooming and panning" as well as "for temporally omitting an object or group of objects" and "for undoing undesired changes" (980). It also provides "easier documentation" and "more detailed, realistic, and elaborated perspectives due to high capability of visualization" (Ibrahim and Rahimian 980). The range of possibilities are numerous with the variety of software such as 2D and 3D as well as software designed for specific purposes like architecture, product design, and bundled technical illustration suites.

Ibrahim and Rahimian "found that although current conventional CAD tools are advantageous for detailed engineering design articulation, they do hinder novice designers' creativity due to their intuitive ideation limitation" (978). Each drawing is mathematically graphed and leaves little room for quick sketches and brainstorming. The rigid digital environment not only inhibits the illustrator's creative process, but it is also difficult to learn. CAD software provides a plethora of tools and shortcuts, but many drafters and students find it daunting. In Wobbe Koning's article, "Teaching 3D Computer Animation to Illustrators: The Instructor and Translator and Technical Director," the author notes the difficulty:

> The concepts and terminology needed to effectively communicate about 3D computer animation's technical side. These concepts and terms are alien to my students; their meaning, eludes the students, and the words do not seem to want to stick. The second area is the software's complexity. Students are often discouraged by the steep learning curve and get lost in the plethora of tools, options, and settings. (81)

Digital software can provide a superfluity of tools, but it also comes at a high learning curve. Bowen supports this notion by agreeing that "embedded in these new forms of production are characteristics that appear to be related to the older, formal (modernist) properties of line, space and colour, but ultimately, they require a different vocabulary and approach to developing images" (220).

Although CAD software is fully equipped with standard and time-saving tools, there are limitations within the programming. In one study, "the student was struggling to overcome the shortcomings of software instead of doing architectural decision makings as the software uses intangible and 2D interface for manipulating 3D objects" (Ibrahim and Rahimian 985). The benefits of CAD programs are numerous, but the learning curve can be high and the process is time consuming.

# CHAPTER 3: EDUCATION AND THE WORKPLACE

Scientific and medical illustration programs differ from the courses taught for drafting. Scientific and medical illustration programs are interdisciplinary. They combine coursework in the sciences and fine arts. Scientific illustration programs are offered at the certificate and bachelor's level. Ben-Ari explains:

> Botanical artists and illustrators have a diverse range of backgrounds and training. They may enter the field from fine art, graphic design, horticulture, landscape design, botany, or general biology. Some are graduates of one of a small number of certificate programs in botanical art and illustration, whereas others are self-taught. Many botanical artists learn their craft in part by studying examples created by other artists--both contemporary artists and the great masters of the past. (5)

Many medical illustration programs are taught within the college of medicine and are offered at the master's level. These students learn how to work as scientists and artists gaining skills such as an attention to detail, researching, as well as how to use artistic media. In order to master traditional tools, scientific and medical illustrators take a variety of art courses. Depending on the institution, some are general art classes while others focus on art applied to the life and physical sciences. Although the materials are similar, the major difference between fine artists and technical illustrators is that fine artists are allowed to take liberties with their subject while technical illustrators must maintain accuracy. This chapter provides information concerning the education of technical illustrators and the issues surrounding the combination of technology and illustration in the curriculum. The chapter also discusses the benefits and challenges that technical illustrators are facing in the workplace due to the introduction of technology.

## Training and Education for Technical Illustrators

Formal training in both the arts and sciences is not always necessary in certain fields of technical illustration. For instance, in the field of botanical illustration, Ben-Ari points out that "most botanical artists and illustrators say that some knowledge of botany is helpful in their work, although many pick up this knowledge on the job" (5). A student can take one of several paths to become a drafter depending on the field of employment. Each route is specific to the nature of the work. Within the field of drafting, differing programs focus on various aspects of engineering such as aeronautics, architecture, automotive, and manufacturing. Although the coursework will shift in focus in relation to the subject, drafters learn the same skills and tools. These classes have a strong focus on mathematics and some programs require technical writing education. Drafting education also depends on the job outlook. Some employers require a degree in a specific field while other employers are content with a more general education combined with adequate experience in the field.

Since technology has expanded the possibilities and the role of the illustrator, researchers are concerned with the current skills taught in the illustration programs. Xavier Greffe believes that the current educational system does not address new skills required by technical illustrators:

> In the present context, this system is outmoded because it ignores the introduction of new elements, which are no longer limited to a mastery over information technology and computer-aided design, in the main activity of artists. In the past, artists depended on agents or agencies for the collective management of these rights, but because many artists work in isolation, artists must now possess communication skills and the ability to manage questions related to intellectual property rights and other issues. (89)

As in many subjects, students are learning about their field of study, but not other skills to help them manage in the business world. This is just one of the areas of concern in technical illustration education.

## Teaching Traditional Versus Digital Methods

Perhaps the biggest debate within the field of technical illustration is the question of teaching traditional versus digital methods. The concerns cited by educators and researchers have been founded by observing a “drop in manual drawing standards over recent years” (McLaren 170). McLaren explains that technical drawing requires “visualization and manipulation of views 2D and 3D, issues of cognitive modeling and transposing images; line quality, accuracy, basic geometry involved in constructing shapes and clarity through application  of accepted conventions” (170). In the past, students learned the skills needed for traditional tools, but this focus changed with the introduction of computers in the arts. In the past, “the experiences of manual drafting courses were devised to help students interpret isometrics, perspectives, and exploded-views to create orthographic and vice versa. The learning was to be illustrative of the conventions and skills integral to product development and reflect the industrial world” (McLaren 172).

For many years, technical illustration educators have tried to combine traditional and digital methods in the curriculum. In an effort to keep up with the development of technology in the workplace, many programs are now shifting the focus away from traditional methods entirely. McLaren explains that “some technology education teachers feel that they are involved in teaching a redundant subject” when incorporating traditional methods into the curriculum (168). With the increase in CAD and other design software, these teachers believe that “there is no place for drawing boards and set squares” (McLaren 168).

However, some teachers and professionals still value the place that traditional methods hold in technical illustration education. In her article, McLaren contrasts the opinions against traditional methods with those of other educators who are “adamant that school students need to ‘know the basics’ of technical drawing before working in a CAD environment” (McLaren168). This concern is rooted in the work produced by CAD students and new professionals entering the field of drafting. McLaren explains, “there are those in higher education and industry who are concerned about the poor standards of CAD drawings produced by engineering and design students, and workplace recruits” (168).

Some researchers feel that the lack of quality in CAD drawings is "due to a lack of understanding of basic geometric construction and the conventions of drafting skills that underpin CAD" (McLaren 168). Furthermore, they affirm that this apparent lack of basic skills can be attributed to the "difficulties learners have in moving from two dimensionally dominant interactions into three dimensions through the principles of drafting" (McLaren 169). Traditionally, drafting students were confined to drawing two dimensional images on paper, but CAD programs now allow them to create images in three dimensions and have the computer software produce two dimensional images from that model. This process eliminates the process of working initially in two dimensions and then converting that image into three dimensions. McLaren cited the work of Sorby and Gorska "who claim that 'hands-on sketching and drawing tend to improve spatial skills more than courses that stress Computer Aided Design methods" (169). The development of these spatial skills is necessary to the understanding and successful transition from two dimensions to three dimensions. According to McLaren, "manual drafting encourages this critical spatial thinking and visualization" (169). However, there is some value in the three dimensional CAD environment. Studies show that "CAD users who have had hands-on problem solving through descriptive geometry and graphics taught using 3D physical models have improved spatial abilities" (McLaren 169). This tug-of-war between traditional and digital methods has made it difficult for educators to conjoin the curricula.

## Work-Related Challenges

While the debate about traditional versus digital methods continues in the classroom, issues have also arisen within the workplace. Greffe comments on these issues:

> Three basic changes are taking place for artists in the digital age. They must become entrepreneurs of their talents by combining new skills with traditionally recognized skills. They must join other workers to form a new category built around intellectuality and

> applied creativity. This last factor determines the number of artists and their place in society. (86)

The artist as entrepreneur model alters not only the skills that the artist must possess, but also the way in which the artist works. Greffe notes that the “artist becomes something of a business organization rather than an isolated worker” (87). Some suggest that the transformation of a worker into an enterprise “is due to the tendency of large enterprises to outsource some of their requirements for greater flexibility and for transferring adjustment costs to others” (Greffe 87). Outsourcing has recently become an issue within the field of technical illustration with many artists unable to find full-time employment. Because of this change, technical illustrators are increasingly accepting contract work.

Another area of concern is that of “deskilling,” an effect noted by Harry Braverman and discussed in Liu’s article. As Liu noted, deskilling occurs when “each stage in the process is gradually converted into simple, repetitive tasks which can be performed by an operator with average levels of intelligence, education and dexterity” (457). This effect is noticeable in artistic professions that traditionally entail eye-hand coordination. Liu observed “workers’ jobs that required a co-ordination of mind and hand in the old days have been fragmented and trivialized into mere physical activities” (457). Because of technology, tasks previously required of and performed by workers have now been digitized for completion by software and hardware. In turn, the deskilled “workers today are less skillful compared to the old generation of craftsmen who had full control over crafts production. In fact, workers have lost the “mastery of the conceptual aspect” of their work” (Liu 457). As technology has increased, illustrators have become more dependent. In an interview, an artist told Liu that “I could try repeatedly to draw a picture by different angles. On computer terminals, revising or changing pictures is easy and fast…. Now, I feel being restricted if I am not allowed to draw on computers’” (458). This reliance is another reason deskilling has become more prominent. As illustrators use less traditional drawing methods, they may gradually lose or never fully acquire such skills.

Deskilling is not the only effect of technology on working illustrators. Technology has also increased productivity and the pressures of the artistic process and output. As Liu states, "digital technologies allow artists to finish works more quickly" (458). On the surface, this might seem advantageous because less production time means higher output, however it also affects the quality of work produced. Although technology has "increased productivity, the rush to create has negatively influenced the work of art. The faster an artist can finish a work, the less effort he or she is willing to make to draw a picture" (Liu 459). Technology not only reduces the number of tasks an illustrator must perform, thereby speeding the process, but it also increases storage and allows for faster communication with the client. Liu explains how illustration information and communication technologies (ICTs) allow for greater and quicker contact between the artist and the client:

> First, ICTs provide a convenient means of communication between editors and cartoonists/illustrators, and therefore have increased the pressure on artistic workers' creative process. The extremely rapid speed and unlimited space of the Internet have resulted in not only an intensification of pressure but also an increase in workload of these artistic workers. (Liu 459)

Illustrators are now seeing a higher, more hurried demand for their work. This pressure also comes from accessibility to illustrators. The illustration job market is now more accessible than ever creating more competition between artists. Illustrators are now competing with one another in a digitized universe where a higher output is often favored over quality. This shift in desirability often pushes the illustrator away from the traditional process and into digital methods.

Deskilling and an increase in production also affect the creativity of a work. The increase in technology has "resulted in a "rush to create" which in effect, undermines the quality and aesthetics of their creations." It has also "trivialized creative work and consequently lowered the value of skilled and famous cartoonists/illustrators" (Liu 462). Liu believes that "degradation of artistic work at the creative stage is less direct and obvious than in manual work at the reproduction stage" (458). The lack of creative skills and the ability to master tools directly affects the quality of a work. Many agree that digital tools not only contribute to deskilling, but that they also inhibit the illustrator as an artist. As perceived by one editor, "comics and illustrations painted by pen are more 'artistic'" (Liu 462). This might be attributed to the tactile sense associated with artistic skill and implementation. As one artist stated, "using pens and brushes is more direct. I can feel how the pen touches on the canvas" (Liu 458).

This competition also comes at a price. Illustrators must also "face the ever-increasing cost of new equipment due to the rapid development" of technology. (Liu 459) Although digital equipment does not need replacing as often as traditional materials, the start-up cost can be very high. "According to Liu's article, an "illustrator's estimation, to equip a graphic design workshop…costs a total of NT$ 1 million (approximately equal to US$ 30,000); moreover, these self-employed illustrators/cartoonists have to continuously pay for renewing devices because old equipment fails to operate with new graphic design programs" creating a "financial burden for artists'" (460).

The wedge between art and technology rests on the inability to duplicate the illustrator's experience in a digital environment. Andres Montenegro states:

> There is no way to replace the studio paradigm with a computer or software that recreates at least the familiarity of recognized tools. This sort of extension of computer technology toward the fine arts realm seems very promising and productive, however years of disdain from the artist's field confirms the confusion installed from the beginning about the idea of using computer graphics in the generation of images. The artist works beforehand with the assumption that he is using distant tools to generate art with the help of computers. (206)

Although many attempts have been made to unite the worlds of art and technology, there are existing issues that continue to plague the artistic process.

Digitizing the Sketchbook

The most significant preliminary stage of design is idea-generation. This is when the illustrator begins ruminating, spawning new ideas and building on old ideas. This involves gathering information, quick sketches, and even written descriptions and note taking. Most often, this process begins in the artist's sketchbook. However, with all of the new technology flooding the artist's toolbox, such as tablets, applications, and high-end software, where does the sketchbook fit in? In the article written by Shaleph J. O'Neill, the author studied the endurance of traditional sketchbooks in a digital world. O'Neill asked the question, "why *do* traditional sketchbooks endure as part of a creative process and why are digital tools not replacing them (yet)?" (308). He concludes:

> Traditional sketchbooks exhibit a range of supporting functions across the creative process that not only support drawing and mark-making but also support memory functions, research activities and the cognitive process of incubation, among others. Digital sketchbooks haven't yet managed to support these functions as fully as they could, but there is no reason to suppose that they couldn't in future. (308)

The study found that traditional sketchbooks provide a personal space, one that is easily accessed and manipulated. The sketchbook records and births ideas, and holds research.

As a pivotal element of the design process, the sketchbook is also a part of the artist. For many artists, the sketchbook is a personal space, not readily shared with others. In O'Neill's study, one artist stated that the sketchbook "becomes quite emotional, there's quite an attachment to it. I think that's why I don't really like people looking at them, because you pour all your initial thoughts feelings and reactions into them" (298). The sketchbook provides a private environment where the artist can work freely, without criticism or judgment. This freedom is necessary to the creative process. Another participant in O'Neill's study described the use of sketchbooks stating that "I really like working with materials that aren't that sophisticated...I think it's a lot more freeing and creative. A bit more playful, so not so serious" (298). There were even statements where artists described cutting and pasting into the sketchbook, adding outside elements and rearranging current pages. From the observations taken in O'Neill's study, it is apparent that the artist enjoys the autonomy and raw materials that a sketchbook provides.

The act of converting that freedom into a digital space, or using current software and applications is an arduous task. Existing programs "seem to offer a range of sketching tools, some more limited than others - pens/brushes, erasing capabilities, colour palettes, storage facilities and even layers and effects - but there is a certain kind of generic quality to all of them" (O'Neill 291). O'Neill's study concludes that in order to create a fully functioning, digital sketchbook the programmers would need to include the elements that make the sketchbook such a vital part of the design process. O'Neill finds that the software would need to include five main functions. O'Neill identifies the search function for the "preparation phase of creativity where an individual is exploring a particular domain through research" (303). This allows the artist to quickly bookmark and browse for material.  The archive "functionality relates again to the preparation phase of creativity and is inextricably linked to the search function" (304). Archiving is the essence of keeping a sketchbook or multiple sketchbooks of ideas. O'Neill also finds that "sharing is an important aspect of evaluation and creative practitioners often share ideas through sowing people their sketchbooks" (305). When designing a project, it is important for the artist to obtain feedback during idea development. According to O'Neill "both drawing and collage functions are related to the preparation and incubation phases of the creative process, where individuals are either gathering or creating visual material in reference to a particular domain, or are manipulating that material in a playful and experimental manner in order to discover something new" (307). The final function is that of editing; a process that "is about organizing the material in a sketchbook and relates to the evaluation phase of creativity where people share ideas" (O'Neill 306). The sketchbook undergoes numerous phases and performs many functions along the way. It is a living organism in the artist’s toolbox that maintains its relevance through transformation. This type of personal interaction and functionality is difficult to reproduce electronically.

## Perception of Traditional Versus Digital Technical Illustrations

Not only must illustrators contend with the traditional versus digital debates concerning finances, deskilling, and education, but they must also address the audience’s perception and interpretation of their work. Technical illustrations were traditionally hand-drawn. These drawings were considered professional work and included scientific illustrations, diagrams, and blueprints. However, as technology has progressed, there has been a shift in the perceived credibility of traditional works. In her article, “Assessing Perceived Credibility of Traditional and Computer Generated Architectural Representations,” Nada Bates-Brkljac states that it is now believed that computer generated images “communicate architectural forms ‘better’ than hand draw forms” (415). Bates-Brkljac also notes that “computer representations can cause misinterpretations and disagreement about their credibility” (415). These observations further complicate the issues surrounding traditional and digital methods. In order to conduct a study of perception, Bates-Brkljac based her study on accuracy, realism, and abstraction:

> *Accuracy* relates, firstly, to the accuracy of the representation of design scheme, its scale, distances, relation to the context and similar. Secondly, it relates to chosen viewpoints (the angle and height) and thirdly, to the accuracy of representations' technique itself (i.e. correctness of the perspective). *Realism* refers to the overall degree of the 'likeness' to the real built environment scenes and the photorealistic style of representation. *Abstraction* refers to the reduction of information provided which is two-fold. First, abstraction relates to the reduced level of detail - a high level of abstraction is when visible attributes (for example of different materials) are only indicated. Second, it relates to the reduced

> amount of information about design (for example structural connections might be omitted). (418)

The representations used in the study were a 3D rendered computer model, watercolor impression, computer generated photomontage, and perspective hand drawings. Upon completion of the study, Bates-Brkljac concluded that “computer generated representations are perceived as more credible and accurate than traditional forms of representations” (424). Bates-Brkljac’s results show the changes in society’s thinking and feeling towards traditional and computer generated images. Although the study focused solely on architectural images, the information gained can be applied to all areas of technical illustration.

## Technology as a Resource

For many years technical illustrators spent time in the field, studying the subject of their work. They became deeply involved in their field through travelling, observation, and research in order to gain knowledge of their subject. Bowen understands that “artists regularly engage in practices of exploring, questioning, researching and making across various contexts. However, ever since our culture has exhibited an increased reliance on computers and a fascination with the Internet and the web, these terms of engagement have become more complex" (219). Some illustrators even made discoveries through their work and became renowned for their many accomplishments. Margaret Mee, a British botanical artist, “discovered and documented new species in her explorations of the Amazon, created stunning art works, and, through both her art and public appearances, became an advocate for Amazonia's preservation” (Ben-Ari 5).

With the vast resources now available electronically, travelling and hands-on research is not always necessary. Thanks to computers and the internet, the illustrator can effortlessly sift through thousands of journals, photographs and stock images, as well as an excess of educational resources without leaving his or her desk. In Tracey Bowen's study, she notes a change in the researching process:

> The first prominent theme is the crucial practice of researching ideas and subject matter for creating work. All the artists at one time or another researched subject matter and resources on the web during the preliminary stages of developing new work. They view the web as a large electronic library, however useful or cumbersome it could be. The artists described their past relationships to libraries as being reconfigured through newly developed researching approaches to the electronic resources of the web. (222)

This abundance of imagery and ideas was reflected when one of her participant's stated "that through the Internet and web she has access to an abundance of current information and imagery that is so important to her work" (Bowen 222). This type of work might be less intensive than Mee's treks through the Amazon, but it alters the experience of hands-on research. Illustrators in the field, such as Mee, were able to observe their subject in the wild and take their own notes. Although many illustrators do not need to travel, some contemporary artists might travel "or roam through national parks and forests, or through their local woods and meadows--recording the plant life that they observe and creating art works that help educate the public about nature's diversity and fragility" (Ben-Ari 5).

## Illustrator Interviews

To further investigate the impact that technology has had on illustrators, I performed e-mail interviews with three professionals in the fields of technical and scientific illustration. I gathered responses from Emily M. Eng, a science illustrator, Ron Rockwell, a technical illustrator, and Gene N. Wright, a science illustrator and professor at the University of Georgia.

Emily M. Eng, Science Illustrator

Emily M. Eng holds a Bachelor's degree in biology with minors in studio art, environmental studies, and religious studies from Santa Clara University. She also obtained a graduate certificate in Science Illustration from California State University. She has been working in the field of scientific illustration for three years. The graduate certificate program offered coursework in both traditional and digital illustration methods, which she feels "refined my art skills and showed me illustration techniques and methods."

Throughout her work, Eng prefers to combine traditional and digital methods. She explains her process:

> Traditionally sketching my subject and then I'll scan those into the computer. I then use Photoshop to figure out the illustration composition. Once the composition (preliminary drawing) is finalized I create the final artwork in the desired medium (watercolor, digital, colored pencil, etc.). For me this process is the fastest. Sketching is quicker by hand and using Photoshop to resize and move things around allows me to create several options quickly before deciding on the final composition. (Eng)

She also relies on technology to communicate and collaborate with clients and colleagues. During the planning phase, she sends the preliminary drawing to the "client for approval." She feels that “technology has helped streamlined the illustration process. It has made the process much quicker and easier. I can almost instantly email a sketch to a Client, have them mark it up with changes and modify it right then.” Eng’s illustration process actively involves the client using technology. She describes the usefulness of technology when working with clients:

> This is a great feature when working with the clients throughout the illustration. Once we agree on a contract (parameters of the illustration) I put together sketches based on

> reference illustration/ pictures/ specimens that we both collect. Next I clean up the sketch and put together a preliminary black and white line drawing. I send that to the Client for approval and once we agree on that I finish the illustration in the medium decided on. (Eng)

We discussed the benefits and disadvantages to both traditional and digital methods. As a working illustrator, she has successfully combined both methods into her illustrations. Even though digital illustration methods have become a vital part of her work, she maintains an enthusiasm for traditional methods. Eng possesses a passion for traditional tools and methods:

> I love traditional illustrations. I enjoy being able to physically hold what I put hours of effort into at the end of the day. Also depending on the work I can sometimes sell my originals, or at least hang them in my home. I also like the wide range of options that I have when using traditional methods. I can combine graphite with watercolor, watercolor with colored pencil, and use different paper to get different effects. I enjoy the challenge of figuring out the best medium to convey the Client's illustration message. (Eng)

However, Eng openly acknowledges the difficulties she faces when working with traditional methods. As many other studies have stated:

> The downside with traditional illustration methods is that it's not as forgiving as digital work. There is no Command Z in watercolor to erase an area you blotched. I also find it more time consuming as you have to plan out what you're going to do. Secondly, the size of the illustration really matters. First there is a finite size to the art paper you can use. And then there is the effect on time, an 8.5x11in painting will take substantially less time than a 20x30in illustration. With some digital illustrations (Adobe Illustrator in particular) you can adjust the image size and everything enlarges automatically without

> losing the quality. Therefore digitally size isn't as much of a factor. Another downside with traditional methods are the materials required. You need a much wider range of traditional tools than digitally. They are a continuous cost and you need to stock them and store them (and know how to use them). (Eng)

Eng's support of digital illustration methods echoes her complaints about traditional methods. Where traditional tools tend to be rigid and much less forgiving, Eng suggest that digital tools offer freedom:

> You don't need to wait for them to dry and as long as you have your computer you're all set…. Digital illustrations are also much more forgiving if you make a mistake (Command Z is magical). This is a great feature when working with Clients as often times you need to make changes. With a digital illustration you can alter a "finished" piece and not start completely over as with traditional mediums. (Eng)

The advantages to digital illustrations are not restricted to their use, but she also cites that the cost associated with purchasing digital tools is "Another advantage is that once you have the computer equipment and software you don't really have any other costs or material needs. Photoshop's paint never runs out and you aren't restricted to the size of the illustration, as with paper sizes in traditional mediums" (Eng).

Digital illustration methods possess qualities that make them invaluable to the illustrator, but do come with drawbacks. Even with the convenience and speed that technology offers, Eng feels that she often invests more time into creating digital artwork. She explains "I also find that there are almost too many options. Deciding what brush to use, what opacity, add to the large time consumption. I find that my precision with digital work slows me down when it comes to sketching." Eng also feels that the amount of time it takes to do a preliminary sketch on the computer is much greater than in traditional drawings. Therefore, she continues to use a traditional sketchbook for idea-generation.

As technology continues to saturate the field of scientific illustration, Eng emphasized that competition requires the illustrator to work both traditionally and digitally depending on the needs of the client. Traditional and digital methods are built on “the same foundation of artist skills (tone, contrast, light and shadow, composition, observation, etc.) and understanding/accuracy of the subject matter are still required to be a strong science illustrator and to have a successful illustration.” Eng often applies traditional techniques to her digital illustrations, “I mimic what I learned to do in watercolor; I add glazes (layers) of a single color and build up the saturation.” Some traditional methods are still widely used in the subfields of scientific illustration where digital methods are not adequate. Eng noted “different science fields prefer different methods. Most botanical plates are still done traditionally as watercolor mimics the fragility of flowers and plants. And botanical black and white plates are hand stippled in pen and ink. Most colleagues concur that stippling is still better and quicker done by hand than digitally.”

Overall, Eng believes that “Technology has just provided scientific illustrators with a wider range of tools. Each medium has its place and purpose and the job of a science illustrator is to determine the best medium to achieve their goal.” She also openly embraces the union of traditional and digital methods in scientific illustrations. Even though digital tools allow more options and freedom, “Traditional methods will always be used as digital methods still have limitations. I don’t consider it a new method verses old method but a growth opportunity to be more effective visual communicators.” In Eng’s opinion, the future of scientific illustration will only be limited by the funding available. Even though scientific illustrations are still sought after:

> Staff positions are becoming rare. Current science illustrators have indicated that once they retire their position won’t be relisted; as research budgets are tight and we’re considered a luxury. Also with the technology-expedited mentality some people have, a

> few Clients don't appreciate how long it actually takes to create an illustration (and what that means in terms of the cost to create the work). I do find myself competing against stock photos/ images as they're cheap and abundant and with other colleagues underbidding their work as paid work isn't that frequent. (Eng)

Ron Rockwell, Technical Illustrator

Ron Rockwell is a technical illustrator, designer, and photographer. He has been working in the field of technical illustration since 1967. He holds an Associate of Arts degree in Commercial Art. Rockwell's career began with "on-the-job training" from a "college technical illustrator teacher who ran a printing shop." He feels that although he holds a college degree, his hands-on training has been the most beneficial to his success as a technical illustrator. His work began with "drawing in pencil with the aid of drafting machines, then inking on vellum." However, in 1986 he began working on a computer and "I haven't touched my pens since. The skills I developed in creating a drawing still come out of my head and fingers, but I don't  have to wash India ink off them anymore."

Rockwell's illustration process is entirely digitized. He even relies on technology for idea-generation, only occasionally sketching with a graphics tablet. When discussing traditional drawing, he admits, "I haven't sketched anything in years." His work typically begins with a photograph of a product or a 3D model. From this, he traces the product in a vector- based illustration program. He puts his years of experience to work and can "usually visualize the finished product before my fingers hit the keyboard." This process varies depending on the product. For instance, "if it's a line drawing, then I create the outline and then work on the inside pieces, layering them so I can hide or show them, lock or unlock them, or just keep things organized."

Just as Eng enjoys the tactile manipulation of traditional art tools, Rockwell does as well. However, "beyond that, I can't find a good reason, basically because then it has to be scanned, tweaked, and optimized for print." He also discussed the ease of reworking errors by adding, "if you make a mistake, you just hit the Undo key." Rockwell further supports digital work due to the "ability to make changes fairly quickly." He can edit and "block the whole thing out, and change camera views at a whim. If I think I want a snail's eye view, but the client wants a bird's eye view, I just move the camera and change the lights a bit and we're done. Doing that traditionally would mean a new sketch and starting completely over."

Throughout the interview, Rockwell frequently supported the decline of traditional methods in the field of technical illustration. Although, the "skill of know HOW to do things the traditional way can't be underestimated. We still have to know how to make things look visually understandable – that's our job." However, "I enjoy working digitally because you don't have to start from scratch if changes are necessary – and they always are."

Even though Rockwell has become skilled and successful in digital illustration methods, the process to learn the skills was arduous. He said that at the time he was transitioning from traditional to digital methods "it took a while because all the software was brand new – version 1 or 1.3." To overcome the challenges of adapting to the digital environment, Rockwell fully dedicated himself to the task of learning the computers and software. He actively searched for new opportunities to broaden his knowledge through self education:

> I belonged to a Mac User group, and became the groups editor just so I could test out new software. I bought and read books by the dozen….I was constantly pushing the software to do something it wasn't intended to do, so I became a voice in the FreeHand forums after the Internet got underway. Then I wrote a book about FreeHand...and got to talk with the people who designed the program. Learning all there was to teach made me a better user of the program, and a better illustrator….Drawing was more consistent and faster, no more shooting Photostats and paste-ups for printing. (Rockwell)

As we discussed the changes in the field of technical illustration due to technology, Rockwell admits that "it changed a boatload of us old-timers." He also stated that he has "lost clients due to companies hiring in-house people to do what I've been doing. I'm pretty sure that technology has had a great deal to do with that, because their learning curve has been easier to tackle." I also questioned Rockwell about the greatest benefit that technology has had on his career. For him, "digital photography has played the largest benefit for me. Prior to getting into digital photography, I had a professional camera outfit that used film. Setting up shots was more complex because what I shot was what I got. If it was too dark, I couldn't see anything" or if "the angle was off" (Rockwell).

Rockwell feels that technology has significantly benefitted the technical illustrator with software, digital photography, and collaboration with clients. In the future, he thinks that technical illustration will be "all 3D" and that there will be no room for traditional illustration methods. Just as Eng states, Rockwell believes that the greatest challenge for future technical illustrators will be financial. He explains that "paying the bills has always been the largest hurdle. Clients want everything cheap. I don't blame them, but you put in ten or twenty or forty hours on a project, you should be paid for it, and they should expect to pay a decent "professional's" wage." Future illustrators will also "contend with learning cures as 3D programs evolve" and when a new program replaces an old one, "you have to more or less forget what you learned before and start all over again with new command names, new features, lost features." Even though Rockwell began on the printing press and knows that holds arduous learning curves with new technology being introduced rapidly, he continues to be an avid supporter of digital methods.

## Gene N. Wright, Professor of Art

Gene N. Wright is employed at the University of Georgia as a Professor of Art and is a scientific illustrator. He has been in the field of science illustration for 24 years and holds a Bachelor's of Fine Art in Science Illustration and a Master's of Science in Medical Illustration. When asked about his training as a science illustrator, Wright feels that without his "Masters Degree in Medical Illustration, I wouldn't have the education to do what I do. The teachings at the Graduate level are preparatory in understanding the philosophy behind the practice as well as the technique and craft."

As an experienced scientific illustrator and professor, Wright has a unique perspective on the use of traditional and digital media. When asked about his preference between traditional illustration methods and digital methods, he explained that he combines them:

> One no longer exists without the other in the industry of illustration for medicine, science or commercial. While there are multiple illustrations that are primarily completed with traditional media, the illustrations ultimately find their way to the computer for final adjusting, manipulation and print. (Wright)

Wright's illustration process begins as a drawing in a sketchbook that is then scanned and manipulated in editing software. The image often goes through several stages to add color, details, and edit the image until it is considered complete.

Although he readily accepts both traditional and digital media in his illustration process, he states that the "only disadvantage, in my opinion, is editing potential. With traditional media, the editing is laborious and unforgiving. If you have to erase, it's gone forever." However, he believes that traditional methods give the illustrator "the ability to be creative and work loosely is best if using traditional media in my opinion. For that reason, traditional media will continue to have its place in science illustration."

Wright also notes that the disadvantage of digital methods is that the "aesthetic quality does not mimic the classic and traditional style that many people favor. The advantage for an illustrator is the ability to try many variations with the ability to save many edited versions as well as the ability to make color, value, transparency and layering of content."

Wright, just as Rockwell, feels that photography has had a great impact on the role of the illustrator. He feels that there is a growing abundance of people that own a camera with the ability to capture high-quality images that are manipulated in digital software. This equipment can be used to create highly detailed images comparable to scientific illustration. However, even with the proper photographic hardware and software, Wright understands that "there is still not a way to replace the illustrator in a situation where there is a dissection and the need to remove information that is irrelevant to the point of the lesson or to conceptualize a particular cross section of information." Although, photography has created new challenges, it has also created the greatest benefit. The speed of taking a photo combined with the ease of "computer scanning and software and printing capabilities have all improved the difficulties that used to be involved in much of the illustrator's problem solving."

Since Wright teaches scientific illustration courses, we discussed how technology has affected scientific illustration education. He explained that technology has made education easier to teach and learn because "there are more examples of good and bad work that are easily accessible. It is easier to demonstrate techniques using technology as the power of editing is so simple." (Wright) Wright also described the challenges that technology has created within the classroom. The abundance of "technology has given the power of illustration to anyone with a computer. That causes a lot of poorly planned an inaccurate illustrations. The care to take the time to be creative has been lost in a way and there is a desire to get it done quicker and hurry to see results."

Although Wright greatly supports the use of technology in the field of scientific illustration education, he acknowledges that both traditional and digital methods "are equally important. The most successful illustrators will have education in both." Traditional illustration methods teach skills like "creativity, aesthetics, patience, and quickness of decision making." While learning digital illustration methods allows for speed, Wright feels that there are other skills that are lacking:

> This is a risky talent and can only be accomplished through training in the traditional media to understand how images are viewed by the audience and what the audience needs to know to learn the educational point. With this understanding, an illustrator can use the

> digital methods to create shortcuts that often can cut the time in half. This is a great asset. (Wright)

Wright is optimistic about the future of scientific illustration. According to him, the field will continue to expand with the growth of technology:

> We will continue to see the same types of illustration, but we will begin to see many more animations and conceptualized imaging of what happens inside cells at the microscopic level. The technology for 3-d scanning will improve and we will see more accurate representations of animal and plant anatomy as well biochemistry and molecular level imagery. (Wright)

However, in scientific illustration courses, “traditional media will fade more and there will be more technology that will assist in demonstrating a visual image of scientific content as the content changes.”

Future scientific illustrators will also see a shift in roles from illustrator to educator. Illustrators will have competition because “the client will be able to accomplish much more with the availability of technology and the quality of the illustration and imagery will diminish. It will be the role of the illustrator to educate and convince the client that it is well worth the money to demonstrate the content accurate and with the desired aesthetic.”

Throughout the interview, Wright explained the issues he faces as an illustrator and an educator. He openly acknowledges the strengths and weaknesses of both traditional and digital media and their impact on the field of scientific illustration. However, he noted that “it should be recognized that the digital methods have been around for such a long time that they too are consider traditional methods. My point is that they are all tools of the trade and one shouldn’t be consider more important or more relevant than the other.”

Through these interviews, it was apparent that the fields of scientific and technical illustration (drafting) are affected differently by technology. The scientific illustrators showed far greater support for traditional illustration methods than the technical illustrator. However, each professional was able to identify both positive and negative aspects of the use of technology.

# CHAPTER 4: CONCLUSION

The combination of illustration and technology has spawned mixed reactions from professionals, educators, researchers, and students. Chang-de Liu explains, “Some cartoonists and illustrators have adapted the use of computers and enjoy a greater productivity resulting from the use of new technologies; yet, some other still rely on their traditional pencil-and-paper skills because these artistic workers insist that the traditional approach is more artistic” (459).

The number of challenges created by the introduction of technology equally matches the number of benefits. Technology has cemented its place in every aspect of life and every field of work. The issue is not whether technology has a place in illustration, but how illustrators can better learn and implement technological tools in their work and how educators can combine digital and traditional methods in the curriculum to produce skilled, successful illustrators.

## Past, Present, and Future Adversities

Since technology has become a staple in the artist’s studio illustrators will continue to face the challenge of combing digital tools with traditional methods. For many years, technical illustration was dependent solely on traditional methods and illustrators were educated in traditional tools. Although those illustrators were successful in their medium, technology has introduced difficulties for seasoned illustrators. The learning curve has proven itself to be a greater challenge than previously thought, causing many established illustrators to struggle with remaining relevant in a digital workplace. Current illustrators also face the difficulties of keeping up with technological advancements both educationally and financially. Technology has transformed the environment in which illustrators work, communicate with clients, and interact with potential employers. There is now a global job market where competition has grown. In the past, illustrators competed locally for employment, now they must have a digital presence and contend with international applicants when applying to a position. This has driven illustrators must learn digital art skills as well as digital social and networking skills.

Future illustrators will also face the problem of global competition. Also, as digital methods become increasingly dominant in both education and the workplace, illustrators will need to gather new skills. According to Kathryn M. Northcut, “as technology creates more graphics possibilities, the challenge for you will be to combine sound principles of design with appropriate technical tools” (307). The pride of being a skillful illustrator has gone beyond mastering tools and techniques; it now must be combined with the ability to create images that are pleasing in all mediums and on various displays.

Technology has changed the way an audience interacts with an illustration. As Mayo states, "Artistic processes have been increasingly digitized but retain their ability to communicate with other media and diverse cannons. As artists tackle new surfaces for display, they will continue to build new relationships with the viewer" (112). With new devices such as tablets and smartphones, many illustrations have become interactive and allow for user participation. Interactivity in technical illustrations challenges the role of the illustrator as well as the audience. New issues will need to be taken into consideration such as user interface design and implementation as well as adjustments to technical illustration education. This will also affect the definition of technical illustrator and the skills needed to succeed. Interactive displays requires a greater knowledge of programming and design. The illustrator will need to adjust to such changes in the creation of new works as well as the perception of technical illustrations. With the introduction of interactivity, the audience is no longer static. The user becomes a dynamic participant and must use new and different skills. Future illustrators will have to take this into consideration when creating more complex, interactive illustrations.

Questions about what defines the technical illustrator will arise in the future. Many software suites can generate illustrations from digital models. This is already prevalent in the field of engineering where the engineer can print blueprints from a model without the aid of a technical illustration background. This problem has also been noted in medical illustration. Morton, Nicholls, and Williams state that "as new technology provides an ever-increasing range of possibilities for using media in new ways in the communication process, the medical illustrator is faced with some doubts about what his or her role might be" (65). With the influx of three dimensional models, the creation of new illustrations becomes less of a necessity. However, technology also creates new outlets for the working illustrator. "What the medical illustration profession has not yet fully realized is the extent to which new technology offers the opportunity to make a much more profound contribution to the provision of healthcare and the way healthcare practitioners are taught" (Morton, Nicholls, and Williams 67). Within the medical profession, illustrators have now taken on the role of creating content for telemedicine and online education. This is an ideal situation because medical illustrators "are already established as communications specialists with knowledge of the attributes and properties of all kinds of media" (Morton, Nicholls, and Williams 68). The technical illustrator's job now requires much more than artistic ability. With advances in technology, the definitions of "illustrator" and "illustration" are becoming broader. An illustration might be a three-dimensional, computer-generated model or it might be

## Opportunities for Further Research

As technology continues to develop and grow in technical illustration, there are many areas for additional research. Not only is it important to study the impacts of new technologies like 3D printing and interactive displays on technical illustration, it is also imperative to understand how this affects the illustrator's skill sets.

One of the least researched areas of the impact of technology on technical illustration is that of deskilling. Few researchers have documented the effects of technology on artistic ability. Liu's study of artists concludes "the introduction of digital technologies has eliminated some of the traditional skills of cartoonists/illustrators. Compared with the older generation, most young cartoonists are less skillful in using pen and paper because they are accustomed to drawing on computer terminals" (462). With illustration increasingly being completed on computers, the loss of traditional drawing skills might not appear vital to the success of technical illustrators. However, illustrators transfer these basic skills into the digital environment. The effects of deskilling have been noticed in engineering as well as in the arts. McLaren's study revolved around the debate as to whether instructors should continue to teach traditional drafting methods. She stated that some professionals are concerned about the quality of work produced by students with only a background in CAD (168). These studies have not specifically followed the effects of deskilling on the field of technical illustration. This is where further research is needed to determine future changes in technical illustration education.

Each of the illustrators that I interviewed described the future of technical illustrators as uncertain due to competition. Technology has opened the door to more competition with other illustrators, stock images, and with unskilled individuals that are able to produce illustrations through the prevalence and ease of technology. Research is necessary to determine how the illustrator can stay relevant in the future.

The field of technical illustration is a vital area of technical communication. Since technical illustrations are used to communicate information visually, it is important for the images to be accurate portrayals of the subject matter. The changes created by computer technology in the field of technical illustration need to be addressed in order to ensure the success of technical communication. These changes have caused technical illustration to experience a major shift in tools, techniques, and training. Traditional practices of technical illustrators include developing spatial and geometric recognition through the mastery of tools such as pens, pencils, drawing boards and scales. Technology has offered technical illustrators a broad set of new tools including unlimited storage, a vast palette and toolset, and new opportunities within their field. However, as seen in this thesis, there is still some debate about the effects of technology on skill, education, and the need for traditional methods. As new illustrators enter the field, the future of technical illustration depends on how these and other issues are resolved.

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