The Electronic Paintbrush:
Computer Graphics and Art Education

by

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Abstract

The overall thesis problem is to determine the major implications of using commercial computer graphics in Western secondary art programs. It is a conceptual study that uses conceptual frameworks established by authors from a variety of fields to show how Western culture has come to hold its views of art, technology, and education; a conceptual study that answers the thesis questions by reviewing the research on computer graphics in education and pertinent writings from the fields of art, art education, computer graphics development, and technology. Based on a critical review of major authors in these domains of knowledge and an emerging body of literature directly related to computer graphics in education, the thesis explains how digitized images function as art objects and shows how computer graphics can be compared to traditional art media in order to define its unique aesthetic, artistic, and cultural influences.

The thesis argues that this technology should not be viewed as a neutral medium or tool in school art rooms but, rather, as a uniquely biased, educationally significant mediator of the way students come to understand and evaluate art. Therefore, art teachers should be reflective practitioners who are aware of the technological bias and cultural forces at work in art rooms where computer graphics come to draw time and funding away from traditional art experiences. Computer graphics should not be dismissed as a marginal tool while, at the same time, an increasing use of computer graphics should not suddenly or uncritically come to dictate the nature of art education.

Aesthetic activity is not a mode of behaviour that should be separate from normal life, nor an adornment. It should be an intrinsic and unifying aspect of all experience but it needs to be cultivated through an adequate and appropriate education. (Sam Black, 1984, p. 23)

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Contents

Preface

I first discovered computer generated imagery as a student and I quickly recognized that there would be implications for art-making. My interest then and now is a fascination with the potential of the new technology and a persistent, vague disappointment with what I see in schools. The lack of quality in much early "computer art" was obvious in the sense that the imagery was often trite or superficial. In my opinion, this is still the case although newer, more powerful microcomputers and sophisticated software are now available.

When I first entered the graduate program I intended to study the contradiction between the computer's potential for art-making and the disappointing results but decided to explore the underlying questions about art education, art-making, and aesthetics first. It turned out to be a fortunate delay. Issues related to the use of computer graphics in the curriculum are now far more important as an increasing number of computers enter the school art rooms. Also, while computer graphics technology developed rapidly as a field of study, new technological developments have become increasingly predictable. This combination of events allows a more meaningful analysis of computer graphics that shows how it is likely to influence art education during the next decade.

Introduction

> More than any other art medium, graphic design is the true expression of our age of exploding information and instant communication. Characteristic of our use-it-once-throw-it-away culture, most graphic design, while it may be reproduced in vast quantities, is remarkably short lived. (McIlhany, 1970. p. 96)

> Computers are changing the world we live in, and will continue to do so. They have already altered the image-making process, and will almost certainly affect the way we teach art. The attitudes teachers take toward computers now will help determine how well our students put them to use later. (Greh, 1990. p. xi)

> Let us first agree that most 'computer art' is old-fashioned, boring, meretricious nonsense; and then that most of it is done by people whose knowledge of contemporary art and its problems is more or less zero; and then that most of this 'art' is actually a demonstration of the power of a few companies' graphics systems; then that most of the 'art' is really graphic design, produced for graphic design-like (and not art-like) reasons; and finally that there is a sort of 'mafia' of people who produce, teach, write about, judge at competitions and generally celebrate and curate this 'art'. (B.R. Smith, 1989. p. 39)

The thesis statement is: computer graphics, as a subject of study, should be included in the school art curriculum because this provides opportunities for unique, worthwhile art experiences and, at the same time, allows students to critically evaluate its technological and cultural bias. The statement responds to views such as those raised by McIlhany who recognized the influence of computer graphics as the technology emerged, Greh who reaffirms McIlhany's view of computer graphics as an important influence on art-making twenty years later and comments on the importance of teachers' attitudes and the impact on education, and B. R. Smith who presents negative comments about "computer art" that warrant a further examination of computer art and the use of computer graphics.

The thesis argues that computer graphics technology can provide educationally valuable art experiences. However, in schools and homes, the technology will be experienced by most students through commercial software packages that carry a bias for art images with limited scope in terms of form and content. Commercial software can be used to make wonderfully executed, creative, and aesthetically pleasing images but simplistic "draw/paint" programs such as the popular Apple products *MacDraw* or *MacPaint*, used in many art rooms because they are inexpensive and easy to learn, rely on a limited set of commands and extensive use of clip-art for much of their appeal. Many students and teachers are attracted to commercial software because of the ability to make quick, simple geometric patterns and shapes that appear as a sharp contrast to messier media where good hand to eye coordination and manual skills are far more important. Such software is also versatile enough to access packaged clip-art and scanned images that meet the expectations of users steeped in the vernacular arts. While there are many opportunities for innovative and unique art with this software, such expression is more time consuming and difficult than image-making that uses the inherent strengths of commercial packages. In other words, uncritical inclusion of clip-art, scanned images, and commercial techniques can limit form, content, and schematic conventions in students' art.

Chapter one defines key concepts and terms, determines the scope of the thesis, and defines the thesis problem as consisting in a widely held, narrow view of computer graphics as a neutral tool or, as merely another tool with the same type of bias as a pencil or paint brush. A critical examination of this view shows how the influence of computer graphics is ignored, underestimated, or misinterpreted. The second chapter shows how digitized art differs from other images. Digitized images are shown to be commercial and scientific products that are seen as significant progress for image-making; a powerful and ubiquitous cultural influence through the vernacular arts and mass media. Chapter three shows how artistic and aesthetic values are influenced by digitization and how computer graphics presents a unique technological influence on individuals and society. Chapter four addresses the educational implications and suggests how this new technology can best be used in the school art room.

The concluding remarks are followed by an appendix with an overview of computer graphics. The appendix is intended for those who are not familiar with the technical terminology and concepts. Some readers may find it useful to read the appendix for the type of background knowledge that is assumed in the body of the thesis.

Chapter I: Computer Graphics and Art Education

> Computers are making unprecedented aesthetic experiences possible and revolutionizing the way art is conceived, created, and perceived. The profound impact of digital technology on the art of the last twenty years and what it portends for the future is only beginning to be appreciated.... No other medium has had such an extraordinary effect on all the visual arts so soon after its inception.... The interactive ability of computers hold the key to radical changes within the artmaking process. (Goodman, 1987. p. 10)

Goodman speaks for those academics who believe increasingly sophisticated computer graphics are having a profound influence on the visual arts. If this is so, if the technology causes "radical changes" in art-making, if it "revolutionizes" art experience, it is important for art education. The quotation raises some important points about computer graphics: the impact on the way art is made, viewed, and distributed; the sudden, unexpected nature of the impact; and, the importance of the interaction between art, artist, and audience. But, it also raises further questions. For example, what is the nature of the impact? Why is a digitized image different from other images? How does the technology manifest itself as a medium and tool? Why is the interactive ability of the computer so significant? Does it limit the art-making experience to an overt cognitive process? Such concerns lead to the thesis questions: (1) What is the nature of a digitized art image and how does it differ from other art images? (2) Are individuals' artistic and aesthetic values influenced by digitized imagery in a way that differs from the way they are influenced by other art imagery, and, if so, how? (3) What are the implications of making and studying such imagery in the art curriculum and, if computer graphics is included, how should the technology be used?

A prior question concerns the choice of topic. Is Goodman's view valid and is it important to analyze the educational implications of computer graphics? I assume that the research is important because of the pervasive way computers and digitized imagery are manifest in all areas of students' lives. Students and adults alike spend a large part of their waking hours in front of a television set where they are exposed to many commercials and other digitized images.[1] Lewis (1990) writes, "The 98 per cent of us with a TV set spend an average of around 30 hours a week watching it" (p. 52). Here, young students see cartoons that are largely computer generated images. Others watch music videos that increasingly rely on digital special effects for their emotional impact. These areas of the popular media are targeted specifically for the young but there are advertising and program promotions on every channel that reach viewers of all ages. Virtually all of these varied images are computer generated. Away from television sets and movie screens, video games present graphic images for the young and computer screens provide them for all age groups. For the vast majority of these images, students fend for themselves as they interpret meaning and judge value while watching TV, playing video games, or working with computers. In many instances the chameleon-like nature of the technology leaves them unaware of a constant exposure to digitized products that are made by different types of graphic artists.

The increasing influence of digitized imagery is also reflected in journals and magazines such as *School Arts* and *Art Education*. These publications have dedicated many issues to computers and other electronic media in order to respond to academics' and teachers' interest in technology but they focus almost exclusively on the most promising and attractive possibilities of the technology.[2] There is sometimes a concern about a lack of funding but this appears to be temporary as dropping costs make powerful microcomputers with sophisticated graphic capacity affordable for schools. Hubbard (1991) illustrates the changing environment as he writes about the growing approval and funding for electronic technology such as video, film, television, and computer generated graphics in school art and music programs. For example, he relates a poignant story about a school with a ten year old request for a new ceramics kiln that was left unanswered while a recent request for electronic equipment in the art room was filled in a few months. As Hubbard notes, teachers who use computer graphics have,

> increased enrollments in art at their schools very substantially, to the point that waiting lists are forcing them to think about cutting back or even abandoning such traditionally stalwart - but under subscribed - art areas as ceramics and replacing them with classes in computing. They find that students who would never normally consider taking art are enrolling in their classes. (p. 9)

This interest in using computers in art education is not surprising considering the wider interest in using computers in other areas of the curriculum. For example, the Apple Classroom of Tomorrow (ACOT), is described by Bowers (1988). In this program, all students in the classroom are in front of a computer from 10:00 a.m. to 2:15 p.m. and presented with a totally "computer-saturated" curriculum during this time. Similarly, Wickens (1992b) describes the program at River Oaks Public School in Oakville, Ont., west of Toronto where 625 Grade 4 students from kindergarten to Grade 8 devote up to 70% of their time to project work on the school's 220 Macintoshes and other computer equipment. Such intensive computer-based programs reflect a perceived importance of computers in all areas of curricula.

I assume art will be incorporated into technologically dependent schools of the future through the increasing reliance on computer graphics technology. It is not a question of whether computers will enter the art room but rather, a matter of how many, how powerful they will be, and how soon they arrive. While it is still too early to state the case definitively, computer technology appears to be a transforming educational force rather than a temporary phenomenon relegated to the sidelines like television sets that were touted as a replacement for teachers when they first entered schools. As Zuk (1990) says, there is an urgent need to be,

> fully conversant with the power, the manipulative forces and the aesthetic impact of high quality electronic art technologies.... To treat the modern electronic art era in a casual way is to delay the inevitable reality that high technology will continue to pervasively enter our lives and to dramatically alter perceptions and experiences. (p. 28)

There is a perceived value in the use of computer technology that will lead students, parents, and administrators to promote its use in all curricula, including art. Therefore, it is desirable to understand a new, powerful technology such as computer graphics and to evaluate its implications for the curriculum. As Goldberg (1986) notes, "Those of us who work in the educational institutions with the young, and indeed the very young, know that for them the new age has arrived. They embrace it unconditionally and enthusiastically" (p. 123).

Definitions and Limitations

The terms, *computer graphics, digitized imagery, computer art, technology,* and, *technique* are used extensively and they must be understood in the context of the thesis. According to Brown (1987), the term *computer graphics* was first used in 1963, "in the report of a group of engineers who had been using computer simulation to investigate the ergonomics of flight-deck design for commercial passenger jets at the Boeing Company" (p. 61). Today, the term *computer graphics* is used extensively to describe all digitized images, and computer graphics is used in all the arts. For example, in the fine arts there are musicals such as *Invisible Sites: A Virtual Sho,* where performers interact on stage with projected computer graphics in a "real time" environment (Wilder, 1992b). In the popular arts, digitization is responsible for most of the novel special film effects and, for those with an esoteric taste for both soft- and hard-core pornography, there are diverse products such as *Erotic Electronic Encounters, Sexxcapades, MacPlaymate,* or the popular *Leisure Suit Larry* series (Lemonick, 1991). Finally, there is an increasing use of sophisticated digitized images in commercial arts.

For example, sport enthusiasts and business executives can invoke a largely transparent mixture of laser discs, digitized voices, animation, and video to view a proposal in a $500,000 presentation by Georgia Institute of Technology's Multimedia Laboratory. This easy access to the digitized world allowed them to move around quickly and freely inside the proposed 1996 Atlanta Olympic Village (Margolis, 1992).

Benthall (1972) says "computer graphics" can be output devices, cathode-ray terminals, or techniques like photo composition and adds, "Artists tend to use the term 'computer graphics' more vaguely, to mean any visual outputs produced under computer control, or even those which are executed manually according to instructions issued by a computer." (pp. 50-51). Ettinger and Rayala (1980) say,

> It is useful to make a distinction between computer graphics and computer art because many articles and books about the visual capabilities of computers refer to generated graphs, diagrams and flow charts which are usually of minimal interest as aesthetic objects.... Computer art, then, loosely refers to images created for their visual effect without necessarily including regard for their utility. (p. 25)

While it is necessary to make such a distinction at times, it can be misleading. Virtually all the software used in schools is developed by commercial interests and the *computer art* students make will be influenced by an overwhelming bias. All computer graphics software and hardware is basically the same. It originated from the scientific-military community that began using computers after World War II and new enhancements come from development funded by scientific or commercial interests. These vested scientific, military, industrial, and commercial interests focus on non-artistic areas such as engineering, medicine, or manufacturing. New developments and an increasingly pervasive distribution system that enforces standards and conventions are guided by the entertainment industries with their priority on popular art, advertisement, special effects, video games, and animation. For example, a pragmatic need for a world-wide communication platform leads to rigid industry standards that define the way all digitized images are made, shown, and distributed. Thus, PHIGS and PHIGS+ are the official world-wide ANSI and ISO standards for storage, editing, structure hierarchy, lighting, shading, curves, and surfaces. Such official standards complement industry *de facto* standards such as *PostScript* that enforce even more limits on imagery (Foley, van Dam, Feiner, and Hughes, 1990).

The term *computer art* is freely interchanged with *computer graphics* in educational literature. Some *computer art* is made overtly as fine art. As such, it is evaluated by the same standards used to evaluate other fine art such as paintings. Such imagery is not boring for everyone, seldom old-fashioned, and rarely limited to graphic designs of non-artists as B. R. Smith's opening quotation suggested. As art, digitized images can be as worthwhile as any other images and a variety of computer mediated art techniques have emerged as an important part of the avant garde art world. However, computer graphics is most prominent in students' lives as popular art; as the cartoons children watch on Saturday mornings, special effects in movies such as *Terminator* or *Star Wars,* and many other mundane images seen everyday in mass media. In the mass media, digitization of the image and the use of computers are not readily apparent. In most animation, special effects, and advertising, artists disguise the digitization process because it is felt to be irrelevant or distracting. Often, such images could be made as well by other means and computers are used because of financial benefits. These images are made with commercial graphics software by professional artists who work in a pragmatic commercial world. They favor techniques and effects that are quick and easy with the software at hand while ignoring alternatives that are time-consuming and expensive. Thus, the term *computer graphics* includes all *digitized imagery* that influences students and their world-view of art. These two terms are used interchangeably while the term, *computer art*, is only used for digitized imagery that is placed in the Western art world as art.

Computer graphics includes all digitized imagery with aesthetic appeal but it also includes microcomputers and software (technology) and the more intangible way individuals conceptualize and proceed when they use the technology (an image-making technique). Lewis Mumford and Jacques Ellul distinguish *technology* from *technique*. Mumford (1952) coined the term, *Technics* and says,

> We ordinarily use the word technology to describe both the field of the practical arts and the systematic study of their operations and products. For the sake of clarity, I prefer to use technics alone to describe the field itself, that part of human activity wherein, by an energetic organization of the process of work, man controls and directs the forces of nature for his own purposes. (p. 15)

This distinction is made because *technology* was generally seen simply as tools and machinery or concrete manifestations of science; as *applied science* or the products of scientific research and thinking applied to problems in everyday life. For a general public, awareness of tools is often superficial and physical manifestations are accepted unquestioningly without recognition of the complex processes that make tools or machines work as they do in society. *Technique*, on the other hand is usually taken to be any set of organized actions with or without material objects. Ellul (1967) sees *technique* as an ubiquitous human striving for the attainment of specific, predetermined results, often towards carelessly examined ends, through standardized means initiated deliberately and rationally. For Ellul, technique becomes an autonomous force that "has fashioned an omnivorous world which obeys its own laws and which has renounced all tradition. Technique no longer rests on tradition, but rather on previous technical procedures; and its evolution is too rapid, too upsetting, to integrate the older traditions" (p. 14). In his view, modern technology is seen as a comprehensive way of life and thought that expands beyond its instrumental character such that,

> The term *technique*, as I use it, does not mean machines, technology, or this or that procedure for attaining an end. In our technological society, *technique* is the *totality of methods rationally arrived at and having absolute efficiency* (for a given stage of development) in *every* field of human activity. Its characteristics are new; the technique of the present has no common measure with that of the past. (p. xxiv)

Ellul's broad definition does not contribute directly to the analysis of computer graphics technology as such but it is thought-provoking since computer graphics always involves sequential procedures and standardized means of attaining largely predetermined results. The ends of the image-maker can only vary within the limitations presented by hardware and software where absolute efficiency is the rule. In this way computer graphics relies on the procedures in both the computer and the image-maker's mind to convert spontaneous, unreflective behavior into behavior that is overtly deliberate and rationalized. As the thesis will argue, this is unlike traditional artistic media where the whole image is visible to the image-maker and the hand has close physical contact with the image. Computers and commercial software present a unique mental and physical interface such that the art-making technique determines the end results more overtly than in painting or drawing. For example, a student with a brush cannot use formal perspective in the same way as when using *CorelDRAW* where perfect 2- and 3-point perspective, based on hidden algorithms, is facilitated by a trivial keystroke while other types of perspective drawing are tedious and difficult.

The discussion will return to the issues raised by Mumford and Ellul, but *technology* and *technique*, are used in a limited way in the thesis. *Technology*, specifically, *computer graphics technology* is taken to be the practical and systematic knowledge, processes, and products within the field: what is said and written about computer graphics, what is known about it; the activities that are involved in developing and working with hardware and software, the systematic processes and procedures; and the concrete objects, tools, and machines such as the computer and printer. This definition broadly combines a notion of active doing and the artifact involved into a coherent whole. *Technique* is taken to be an artistic method of image-making. Specifically, the overtly sequential, cognitive, process-like image-making technique required with computer graphics is shown to be quantitatively different from techniques such as drawing or painting where a holistic, manual skill-dependent technique is required.

Limitations.

The thesis is intended to address educational issues and concerns that relate to high school students in Western societies. Thus the way older students approach art and aesthetic experiences is the basis of the thesis arguments which do not deal with the complexities of developmental theory. Furthermore, the main concerns raised about computer graphics in this context are limited to secondary students' uncritical use of "low-end" hardware and software products that are the cheapest, easiest to use, and most common in schools. Other software discussed in the thesis are intended to illustrate clearly the way computer graphics technology influences individuals and society as a whole. Typical software includes simple "draw/paint" packages such as *MacDraw*, *SuperPaint*, or *MacPaint* and more sophisticated packages that are also used by professionals such as *CricketDRAW*, *FreeHand*, and *ImageStudio*. These products are readily available in schools and homes where students have access to microcomputers.[3]

It is assumed that an understanding of computer graphics can contribute to the development of programs that first and foremost provide worthwhile knowledge and understanding about artistic and aesthetic practices, values, sensibilities, attitudes, and theory. It can also inform the efforts to include art programs in a broader schooling that strives to prepare students for life in Western society. However, it is assumed that the emphasis of such an art education is a breadth of conceptual knowledge about art and the all-important art-making experiences that foster aesthetic sensibilities and understandings, rather than art training for extrinsic purposes or art programs that focus primarily on conceptual and cognitive understandings. This definition of art education is expanded in chapter four. Thus, the scholarly and social significance of the research is closely linked through the evaluation of digitized art in terms of its aesthetic and non-aesthetic values and its potential in the art room.[4]

Objectives and Problems

The thesis will defend the view to be articulated regarding how computer graphics should be used in art curricula. It should also raise an awareness of benefits, controversies, and complications associated with computer graphics. As Richmond (1990) writes in another context, this type of research should be informative for educators who "assess priorities, develop workshops, focus lectures, model teaching approaches and develop students' individual strengths" (p. 3). The thesis does not address these concerns directly but the research can inform workshops and lectures that address the use of computer graphics in the art curriculum. In pragmatic terms, teachers cannot teach painting or ceramics to students during the same time and with the same funding used to teach them about computer graphics. Some existing art activities are displaced by time and money spent on computer graphics unless more resources are added to the curriculum (Hubbard 1991). Thus, the thesis suggests that art teachers must have a full understanding of computer graphics if students are to benefit from the technology.

The "Narrow" View.

The thesis problem, overall, is to determine and describe the major educational implications of the way commercial computer graphics technology is used by students in schools. It is an important problem because of the increasing influence of such products and the unique bias that is associated with this technology. The problem is most clearly seen through a critique of the "narrow" view that fails to account for the unique influence of commercial graphics software commonly used in art rooms and homes. It is a view that stems from a lack of understanding about the way digitized images in the mass media and art-making with commercial software come to influence students when the technology is approached uncritically.

Many views in the educational literature are problematic because they fail to approach the new technology and its related techniques critically. Specifically, there is a pervasive view that sees computer graphics as a neutral tool. This is demonstrated by writers such as D'Angelo (1988), Hubbard (1991), McWhinnie (1989a), and Prueitt (1984). The thesis argues that, while all art tools carry some bias that influence both form and content, the commercial software and hardware that is available to students holds a technological and cultural bias that is far more powerful than other traditional art media such as drawing or painting because of its unique nature and the way it is incorporated into the culture. Other writers such as Kitson (1991), Hickman (1991), and Palyka (1989), suggest that the technological bias can be eliminated by teaching programming skills. In this respect, the thesis argues that, while these authors recognize bias and limitations in the "packaged" approach, they fail to see the bias of the programming languages that are available to students in the art room. They also fail to recognize the practical limitations of time and resources required for such non-art skill development. Finally, there are those who suggest that computer graphics should be taught as a language skill or as a form of *visual literacy* that lets students understand (read) images and express themselves (write) with the, "tool skills of image making and manipulation" (Hubbard, 1991, p. 12) or, "images in motion" skills (Loveless, 1990, p. 203). This view is closely linked to a notion that art education should focus on cognitive interactions and understandings of art objects.[5]

The narrow view originates from the scientific-commercial bias of the developers and their expert knowledge which is largely hidden from artists and art teachers. The term *scientific-commercial* is used to indicate that computer graphics is developed primarily to make practical, precise, cost effective imagery. As Foley, van Dam, Feiner, and Hughes (1990) write, "By making communication more efficient, graphics makes possible higher-quality and more precise results or products, greater productivity, and lower analysis and design costs"

(p. 4). Their influential text, *Computer Graphics: Principles and Practice*, is used in post-secondary courses and they state clearly that the emphasis is to understand and develop applications that suit the areas where such imagery is most common. They say the most common application is user interfaces in commercial software such as word processors, spreadsheets, and publishing packages. Next is 2- and 3-D images for mathematical, physical, and economic functions. "All these are used to present meaningfully and concisely the trends and patterns gleaned from data, so as to clarify complex phenomena and to facilitate informed decision making" (p. 5). Commercial art is near the bottom of their list and,

> here, computer graphics is used to produce pictures that express a message and attract attention.... slide production for commercial, scientific, or educational presentations is another cost-effective use of graphics, given the steeply rising labor costs of the traditional means of creating such material. (p. 6)

Most developers assume that computers are neutral tools. Steve Jobs, the founders of Apple Computer Inc., says, "I'm a tool builder.... Tools bring out the intellect and creativity in all of us" (Daly, 1992, p. 8). Similarly, Phillippe Kahn, founder of Borland International Inc., creators of Turbo Pascal, Sidekick, Quattro Pro, says, "Computers are tools, and they have to become better tools" (Gillin, 1992b, p. 29). These developers see computers as neutral tools that can be used for good or evil; they assume that there is always "direct control" of the technology. Furthermore, they assume that the technology represents significant, even revolutionary, technological progress, a major step forward for image-making. This is also the case for many academics who fail to recognize how individuals necessarily incorporate the technological bias into a world-view. For example, as McCorduck (1985) says, "in the last half of the calamitous twentieth century, the human race has fashioned the most civilized and human tool ever made. It is called the computer. Having fashioned it, we have in the main embraced it rapturously" (p. 15). Or, as Walters, Hodges, and Simmons (1988) say, "Computers are tools. The unique power of these tools as well as their particular limitations stem from the special way in which computers treat the material of art and music" (p. 100). Walters, Hodges, and Simmons separate ends from means. They see computers as a neutral way of manipulating pixels and insist that, "the artist can directly control this synthesis" (p. 103).

Most software developers come from computing science which is the study of how data are manipulated or presented as information that expand or compress natural concepts of "real" time and space without concern for the way individuals make meaning. That is, the study assumes that computer technology will operate within a fixed reality. This is Prueitt's (1984) view: "Perhaps someday the computer will be considered humanity's finest artistic tool. It *is* merely a tool.... Computer art, like all art, is a product of the human mind, conceived through studious reverie" (p. 2). Similarly, McWhinnie (1989a) insists computers do not alter his personal or creative vision and that he has not, by any stretch of the imagination, become a slave to the machine. He assumes that because there is still a smell of paint and a taste of clay in his studio there is no significant change and says, "For me at least, the personal computer has become yet another tool for the artist and designer" (p. 167). Nigel Holmes, an influential graphics artist as the force behind *Time* magazine's graphics for fourteen years, was asked how computers affected his style. He replied,

> I'll still do my "real" drawing straight from the brain to the paper, through the pencil - and then scan that in and do with the computer what I used to do with templates or Rapidographs. As far as the drawing is concerned, the software has made no difference in how I draw. I defy people to recognize the difference between something I produce on a computer and something I drew by hand. (Silverstone, 1991, p. 55)

Holmes insists there is no difference in the results but explains how his earlier drawings did not suit contemporary needs for graphic illustrations and forced him to adopt new technology. He says,

> it occurred to me that what was making me nervous about drawing and getting into print - because I could draw quite nicely - was that my drawings looked like old-fashioned figure studies. I was trained that way as an illustrator. But they didn't look that good in print. So I developed a completely opposite way of illustrating, which was to do my hand drawing, then become like a machine and superimpose a purely mechanical rendering of those lines into the smoothest, tightest, finest lines that I could draw. (p. 18)

What Holmes fails to acknowledge is the way in which increasing reliance on computer graphics and desktop publishing in the mass media creates new standards and preferences for imagery that are compatible with computer graphics technology and techniques.[6] This influence is recognized by Peterson (1993), another illustrator, who wonders if the computer is more an extension of the hand or the mind and asks, "did you use so many ovals in your work before they were so easy to create" (p. 24)? Peterson is writing about both the obvious and more subtle influence of computer graphics on designers who used to work with ideas in their mind and thumbnail sketches before the advent of the new technology. He suggests fluid mental thoughts and throwaway sketches are now put on the screen where they assume sharp edges, perfect corners, and sophisticated fonts that closely resemble the finished product. Such imagery becomes objectified and concrete in a way that the immaterial idea and quick, rough sketch do not. Once the screen image is created, it is an advantage to manipulate the image because of the tool's propensity for working on such details and, instead of starting over, there may be a tendency to line things up, fine-tune the kerning, or adjust proportions. Similarly, Wilson (1986) explains how many artists use computers to assist them with their initial work in various media, such as clay or paint, then continue without further regard for the computer which, supposedly, fades into the background. However, as Wilson (1986) adds, "Even though the intention is to continue to work in the same directions as before the advent of the computer, the course of the work may change.... New ways of thinking and doing are engendered by the prevalent tools" (p. 21).

Allison (1992) provides another example. Wolfgang Weingart from the Basel School of Design in Switzerland is considered one of the twentieth century's most important typographer-designers. His teaching philosophy includes the notion that "there is no difference between a pencil and paper and a computer" (p. 19). In Weingart's school the Macintosh is part of every student's education. They are encouraged to view the machine as a mere tool, with its own possibilities and limitations, just like any other tool. "If a student cannot draw with a pencil or cannot mix colors with a brush, he cannot go into the computer," comments Weingart and adds, "you might need years to do by hand what you can do on the computer in a day. But that has nothing to do with a new world of visual expression. I don't see any way to get a new visual vocabulary through these machines" (p. 20). Such views fail to recognize how design has already changed to accommodate computer technology.

Writers such as Kitson (1991), Hickman (1991), and Roszak (1986) recognize the bias of computers and suggest that direct programming experience is necessary. Hickman (1991) says, "Most software today was modeled on some existing medium or application; what artists must do is expand upon what already exists. To do so they have to be able to create their own software" (p. 50). There are a number of problems with this view. First, inexpensive, readily available, easy-to-use commercial software is popular with students and teachers. Second, there is no time to teach programming in the art curriculum. Even simple programming languages require many hours of practice. And, third, it is not clear that intimate working knowledge of bits, bytes, and pixels provides a better understanding of the intrinsic nature of the medium. It is simplistic to think that programming will reveal the inherent bias of technology since all languages carry the philosophy of the industry just as surely as commercial software. This view can lead to non-art-like uses of computer graphics in the art room. For example, Palyka (1989) teaches "Introduction to 'C' Programming with Graphics Application" because,

> The positive side effect of the class is that the better students gain new skills with which to make a living. Artists always need job skills that make use of their talents. Now they can do one kind of art on a personal level and can make their living by programming computers. (p. 45)

Palyka's statement is acceptable to many students, parents, and administrators who keep a weather eye on the workplace where computer graphics are generally seen as inevitable progress.

A view of computers or programming languages as neutral tools is problematic since they shape reality despite the assertions to the contrary. Art-makers such as Weingart, Prueitt, McWhinnie, and Holmes fail to acknowledge the extent of the technological influence on the images they make and the way they engage art-making at all levels. These writers and artists fail to recognize that their work must be structured to suit the digitization process which means they cannot use computers as neutral tools. As Shore (1986) says, "The impact of technology goes far beyond, and far deeper, than the use of hardware and process, or the immediate practical need or service. It influences the patterns of significant behavior, ceremonies of social existence, and relationships among human beings" (p. 87). Uncritical use can lead to a focus on simplistic object-oriented or bit-mapped imagery or the use of scanned images and "clip-art" that provide "slick" mass media effects because such techniques and imagery are quick and easy with commercial "draw/paint" software.

Most critics of computer graphics do not address these concerns. For example, R. S. Smith (1989) calls all computer art old-fashioned, boring nonsense and Ellul (1990) suggests it is either dreadful or ridiculous. Roszak (1986) considers most computer graphics imagery in the classroom an "eyesore" and, "aesthetically degraded, even ugly" (p. 52) and asks if enthusiasts are aware of what, "long-term visual exposure to such junk art does to children's taste? Even worse, some teachers try to make use of the computer's low-grade graphic abilities to teach 'art,' lowering the subject to the level of the machine" (p. 53). Roszak detests the neat, predictable, private and self-contained reality created on the computer with exact logic, selected data points, and predictable-parameters that become reality rather than an overtly recognized fantasy world. More temperate voices such as Nadin (1989) merely ask why such art "seems to exhaust itself at the first encounter" (p. 43).

Other critics such as Kruger (1983) and Barzun (1989) suggest the problem is one of overexposure and oversupply. They do not identify substantive characteristics or qualities of digitized art that would make it inferior to other art. Such criticism reflects a more focused view of the popular arts as inferior forms of artistic expression by such influential writers as Theodor Adorno (1984, 1991) and Pierre Bourdieu (1990) as well as the broader concerns for technological determinism expressed by such writers as Jacques Ellul (1967, 1980, 1990) and George Grant (1969). These critiques are problematic not only because they fail to explain how the unique influence of computer graphics is related to popular art and scientific progress that suggest technological determinism, but also because they fail to show how computers can provide worthwhile art experiences. The emergence of computer art and digitized imagery in general is never entirely technologically determined. It is primarily shaped by economic forces. Thus, the technology is neither the panacea for art education Hubbard (1991) offers, nor inevitable technological domination of imagery as critics such as Ellul (1990) propose.

Chapter I: Summary.

1. The thesis questions ask how digitized art images differ from other images and how is this important for art education? Specifically, what is the nature of digitized art and how does it differ from other art? Are individuals' values influenced by digitized imagery in a way that differs from the way they are influenced by other imagery, and, if so, how? What are the implications of making and studying this technology in schools and, if it is included, how should it be used?

2. The "narrow" view of computer graphics technology represented in the writings of many influential software developers, academics, and teachers fails to show how cultural and technological influences can change an individual's art experiences. The view includes the notion that computer graphics is a neutral tool for art-makers and that the technology constitutes revolutionary progress in art-making. It can lead to unfounded fears for some and uncritical enthusiasm for using computer graphics in schools for others.

Chapter II: Computer Art

> The change wrought by the introduction of electronic media and computer graphics is profound. It is not simply a matter of 'technique' or style, because the new media have already reshaped design specializations as we describe them today, and it is already clear that these changes have wide cultural significance comparable to the great technological innovations in agriculture in the eighteenth century and those surrounding the printed word and printed imagery in the fifteenth and mid-nineteenth centuries. (Kitson, 1991, p. 541)

As Kitson writes, the advent of computer graphics is profound and it changes perceptions of art. But, what is the nature of the digitized image and how does it differ from other images? The answer to this question is of paramount importance if we intend to incorporate computer graphics in the art curriculum. Digitized imagery is unique because it is ultimately realized as pure numbers that translate into bits, bytes, and pixels without any scope for error or variation. This provides an inherent ability for such images to be copied perfectly with ease and speed without any need to distinguish an original from a copy; they are cloned rather than copied and an original is the same as a copy in the mass media. Digitization also provides a means to easily and cheaply distribute images almost anywhere in the world with unprecedented speed and accuracy. And, digitization provides flexibility and adaptability to all art images because the technology allows non-digitized or "analog" images to be incorporated into a digitized world. Any image digitized by a scanner or frame grabber is absorbed into the "sameness" with imagery made by measurements, samplings, or direct manipulations in a computer's memory. In other words, a digitized image is the most advantageous from a scientific-commercial perspective where such things as accuracy, cost effectiveness, communicability, and innovative graphic imagery are important; it is the most adaptable and responsive image-making technology in terms of addressing the scientific-commercial needs of a diverse, contemporary Western society.

Computer Graphics

Computer graphics includes such diverse images as the scanned Mucha painting *StartupScreen* on the Macintosh, *PrintShop* birthday cards made by students in schools, illustrations of brain scans in popular magazines, satellite "photos" of Jupiter on the news, and the fonts and icons on the computer screen. All are made by software and hardware based on shared processing logic, governed by similar industry standards, and based on the same theories. They share assumptions about how images should be presented in 2-D and 3-D perspective based on a set of theories and values that rely on scientific realism for their impact. The software lends itself to perfect geometric figures, precise gradations of color and shade, and quick replication of existing shapes. This type of realism is considerably different from the realism achieved by artists like Alex Colville or Christopher Pratt. It is a difference between modeling an aspect of the physical world and interpreting the physical world in aesthetic terms. This inherent bias for scientific realism is the case for simple draw/paint software students use every day and for the complex educational software such as *Treasures of the Smithsonian*, a CD and text package used in American schools. This exciting CD, used with a Philips Compact Disc Interactive Player, lets students tour the fourteen museums in the Smithsonian Institution. It combines music, video, and narration to let students retrieve or manipulate specific images and data at different levels of detail (Brady, 1992). The natural world illustrated by the Smithsonian as well as other readily available images such as the digitized fine art works from major art museums that are distributed on CD's can be copied and manipulated within the same parameters shared by the "draw/paint" software students use for games and non-artistic illustrations.[7]

In short, the tools and images available to teachers are dominated by scientific-commercial interests. Some students may be exposed to digitized fine art images but they are all inundated with amazing digitized imagery in films, videos, and magazines. The professionals who work with the technology have access to powerful hardware and programming expertise well beyond the grasp of most students but the commercial software that mimics the latest movie techniques are on a student's computer almost as soon as the movie is in the theater. For example, a new technique called "Morphing" was widely publicized with the release of the movie, *Terminator II.* This is a method of digitization that changes one shape into another on a film screen with great realistic effect. However, the "Morphing" software that was available on the Macintosh within weeks was an impoverished version of professional programs developed by ILM studios for movies and advertisements. Students can only achieve a limited degree of "Morphing" and they are virtually forced to work with a face or other restricted content that lends itself to being "morphed" without simply looking like "fades" or other film techniques. This is an example of how the potential of an innovative technique used by professional artists with access to specialized equipment is replaced in schools and homes by simplistic "fill-in-the-blanks" software programs with limited potential for form or content. Students must rely on commercially available software and they are drawn to programmed features and commands that make certain images easier to make than others or to images that are only possible with the use of scanners or clip-art.

A Brief History.

The educational potential of computer graphics emerged virtually full-blown along with inexpensive raster graphics. *Raster displays* (horizontal lines forming a matrix of individual pixels representing the screen image) allowed *primitives* such as lines or solid areas to be stored in buffers as component pixels. The complete image was refreshed and viewed as a totality while the changes were made on the screen. Limitations of the Cartesian coordinate system were initially overcome by programs that used selected vertices to specify lines and polygons that were manipulated by algorithms (object-oriented graphics). Then, multiple or layered bit-maps provided color and gray scales and, finally, "Z-buffering" techniques allowed for the manipulation of multiplane bit-maps that automatically displayed those pixels on the screen that are closest to the viewer (solid modeling). These technical developments allowed subsequent image-making and the later development relied on more power and storage to explore the possibilities that were promised by the technology as it stood in the early 1980s. Developers focused on taking advantage of rapidly advancing hardware with techniques such as solid modeling and fractal geometry both through raw processing power and, eventually, through the way image features could be mediated by the image-maker. As Foley, van Dam, Feiner, and Hughes (1990) note, the user interface is the "last frontier" in providing computing to a wide variety of users since costs are low enough to provide significant computing capability and the "quality of the user interface often determines whether users enjoy or despise a system, whether the designers of the system are praised or damned, whether a system succeeds or fails in the market" (p. 347).

The technology has evolved rapidly since computer art was first made on oscilloscope screens in the 1950s. The electronic computers used for such art were first developed to solve U.S. Army ballistic problems during World War II and the combined military-scientific research provided the basic theories and engineering concepts used in contemporary computers. A few scientists, such as Ben Lapofsky and Herbert Franke, used analog computers to generate images on voltage-controlled oscilloscopes which were then photographed from the CRT. Such images were precursors of computer graphics as the first images generated and controlled by the computer as pure numbers and viewed on a screen as they were made. However, oscilloscope art and simple printer images were not influential in terms of artistic form or content and the artists were excluded from development by scientists, technicians, and scholars in large military, commercial, or educational institutions. This early limited inclusion of computer graphics in the fine art world and its close links to the vernacular arts has contributed to the low status of digitized imagery as fine art. As Goodman (1987) writes, "rejection of computer art was initially based as much on the dubious aesthetic quality of early computer graphics accomplished by scientists, who were mislabeled as artists, as on a fear of the machine itself" (p. 15).

During the next ten years there was increasing use of computers for artistic purposes by people such as Gyorgy Kepes, Billy Klüver, and Robert Rauschenberg. They established a formal alliance between artists and scientists in large institutions where powerful computers were located but rapid development of the hardware and software remained dominated by scientific, business, and military interests. This initial venture by computer scientists into the art world took place along with the wider interest in scientific art images during the 1960s when scientists-artists first showed the wondrous landscapes discovered by new technology that could photograph the world from satellites and illustrate the innermost part of a molecule through electron microscopes. For example, Gyorgy Kepes' innovative book, *The New Landscape in Art and Science*, helped change the view of the natural world because scientific images were shown in popular magazines, newspapers, and on television as art rather than as scientific explanations of events. By the late-1960s, digitized imagery became prominent and geometric forms, such as Lissajour figures or vector graphics, were common in art and technology exhibits. Such exhibits included a variety of computer-mediated art emphasizing holography, lasers, and other art forms relying on light and movement. Like earlier oscilloscope art, these uses of computers were only influential by calling attention to technology in a general sense. They did not provide meaningful imagery that held interest as art once the novelty wore off.

The seminal work by Ian Sutherland at MIT in his 1963 Ph.D. thesis, *Sketchpad*, was the first indicator of what was to come. He showed how interactive, real-time computer graphics was possible and practical. His work led to "draw" programs that manipulated images in the computer's main memory; on-line, real-time digitized imagery. Such software combined with the Apple microcomputer and similar technology during the late 1970s to finally allow artists and educators full access to computer graphics. They were now able to escape the narrow confines of the technological and scientific realms through affordable, "user-friendly" hardware and software. At the same time, a powerful entertainment industry began using computer graphics extensively and, for the first time, major development was influenced by forces outside the mainstream scientific and business communities. Finally, by 1980, raster graphics became a dominant influence on digitized imagery because of the increasing speed and memory capacity of the new generation of microcomputers. This resulted in the familiar, sophisticated three-dimensional, colored, shaded, textured images with reflections and transparency; images taken for granted in the mass media today.

The influential entertainment industry is now a major force in the development and utilization of computer graphics. In 1981, Michael Crichton's film, *Looker*, introduced 3-D computer graphics to feature films and this was quickly followed by such features as Disney's *TRON* in 1982, which took place inside a video game, and the prolific Lucasfilms, Ltd. productions of, *Star Trek II* and *Return of the Jedi*. Corliss (1992) notes how the 1992 Oscar for Visual Effects was a choice between three of the special computer graphics effects that emerged from George Lucas' Industrial Light & Magic shop (ILM). ILM provided digital effects for films such as *Young Sherlock Holmes*, *The Lawnmower Man*, *Willow*, *Back to the Future*, and *Memoirs of an Invisible Man*. They also made the commercials that change a car into a running tiger for Exxon and a man's face into a block for Schick razors. The 1992 winner was *Terminator 2: Judgment Day* while *Hook* and *Backdraft* were the losers. This provided ILM studios with its seventh Oscar and they blithely say, "We have conquered the physical properties of nature.... A real human being - I think we'll get it.... Not much is impossible" (Corliss, 1992, p. 65). The continuing influence of the mass media and commercial forces of society cannot be ignored by teachers who use computers. Such influence directly affects aesthetic and pragmatic values. As Bennett (1993) notes,

> Computer graphics technologies and techniques are now quite commonplace in cartoons and other animation sequences. Major Disney successes such as *Aladdin* and *Beauty and the Beast* are prime examples. If you've ever seen the famous ballroom sequence in *Beauty and the Beast*, you'll understand why the techniques have so many animation professionals excited - and worried. (p. 35)

Software and Programs.

Nadin (1985) says that a "computer is not a tool - only programs qualify as tools" (p. 45). By contrast, Curtiss (1987) defines tools as all "implements, utensils, instruments, machines, and devices that have been created to facilitate visual statement making. They include pencils, brushes, chisels, drill presses, potter's wheels, cameras, and are too many to enumerate completely" (p. 96). In either case, computer graphics necessarily involves a unique procedural method of dealing with composition, color, perspective, and so forth because of the common command structure of all software and the similarity of the hardware platforms. Imagery cannot be made in a tactile, holistic manner when it is digitized. It is conceived and made procedurally and conceptually; a different type of thinking and working where tools shape thinking far more readily than the pencil or brush. Each software product is slightly different but all rely on a limited set of "tools" or commands that must be used one at a time in a restricted sequence. This forces image-makers into procedural paths in thinking about the image and in the actual image-making. My own experience bears out these statements. I used *FreeHand* and *Image Studio* extensively to obtain a depth of understanding and experience with both object-oriented and bit-mapping software. I have also experimented with a variety of other software products in order to gain a breath of experience with the professional or esoteric software that exemplifies the developments in the field. Some of the software aimed at professional artists demonstrate most clearly how strict procedural methods of image-making are always necessary. For example, Schmal's (1992) review of *Ray Dream Designer 2.02* shows how *SceneBuilder* (the assembly and lighting application) can only be invoked after using *LightForge's* (the image-generating application) modeling modules to create 3-D elements by extruding objects or "lathing" them. The user must first decide how to create the three-dimensional object from within two sets of parameters. Then, the object is manipulated further by another set of parameters that adds shade and light. *Macworld* has a regular section that describes how one of the article illustrations was made. A review of the illustrations shows how virtually all the artists use previously made drawings or photographs to produce images which are fully thought out before the work begins. All these artists write about "cleaning up" or "assembling" their scanned images through application of consecutive command features and the iterative use of several packages as they assemble the illustrations. Such procedural and restricted ways of manipulating images are not always obvious in "low-end" software but students must necessarily use "drawing" tools correctly before they can use "fill" features just as they must "cut" and "paste" in sequences and ways that are rigorously enforced by the nature of each object-oriented or bit-mapping program used.

By definition, a digitized image is a series of electronic switches that are completely represented and defined mathematically as either "1" or "0" (on or off). The binary digits as bits and bytes make up the pixels on the screen and everything else is a matter of what algorithm, how many pixels or, in the case of a pixel of color, how many sub pixels or layers are used. There are huge numbers of binary digits involved at times and complex sets of rules determine how static and animated images are presented but they all break down into the same basic binary elements. Unlike other imagery, digitized imagery can be manipulated with complete accuracy that leaves no room for error or variation because of the ability to store vast amounts of numerical information and a reliance on strict logical procedures to manipulate the data. Computer graphics technology in general and commercial software specifically focus on the way an image is made rather than on what is made. The technology relies on the laws of reflection and refraction, linear perspective, sectioning, solid modeling, and, as an ever present, underlying theory, simple Boolean set operations such as union, difference, and intersection. Thus, while there is some debate about how we define the "tools" used, there is no escaping the ever present procedural thinking that is an inherent part of these Boolean operations.

In my own work with *Aldus FreeHand, SuperPaint,* and *MacDraft,* I experimented with images that were not preconceived yet it is quite evident that images are "constructed" and that they can be evaluated as distinct, manageable layers, sections, and settings. I can show a student how I make such imagery and allow the student to repeat the process in a way that is not possible with a pencil or paint brush where the manual skill is not translated into sequential commands and distinct key strokes. There is holistic involvement (also iterative and interactive to some extent) with media such as pencil or paint that is not possible with computer graphics where there is a need for more preconception of imagery bound by the CRT while necessarily sequential steps are undone or saved as required. Such interactive iterative experimentation where imagery is strongly influenced by software parameters that can only work sequentially and must be undone or saved in distinct phases is different from the holistic influence of form and content that provides the important "feed-back" evaluation when working with analog art media.

Understanding the influence of programs or software shows how the dominance of scientific reasoning and overt emphasis on non-artistic ends led to overwhelming cultural influence from computer graphics. Development and control of computer graphics technology by the scientific-commercial sector determine what imagery is possible and easiest; what is most likely to be made. Developers are primarily concerned with specific areas of human experience and perception; areas that are not necessarily related to the artistic and aesthetic experiences that are important for art-making or art education ends. It is technology for imagery that represents scientific reality through color, perspective, surface quality, and animation. The techniques are primarily meant to illustrate processes important to the scientific community and to provide cost effective, stimulating, novel images that attract and engage consumers for a short while as advertisement or amusement in the pervasive mass media. The current emphasis is on making solid models that are simplistic in artistic terms but lend themselves to efficient scientific models, stylized commercial images for advertisements in the mass media, and innovative special effects in movies. Such scientific-commercial imagery can be quite engaging as the perfectly shaped and colored "photographs" from the latest space probes show but, as Nadin (1989) writes,

> Since any description - in the philosophic form of discourse or in mathematical-logical formalism - is, after all, incomplete and thus subjective, once such descriptions become generative tools in the form of procedures or programs, they act upon the data (the 'matter' of electronic art) as a mold. The fingerprint of those who designed them gets marked in the image or the sounds generated. (p. 45)

The Influence of Commercial Software.

Dr. Nicolas Negroponte, a major force in new computer graphics development as founder and director of MIT Media Laboratory, is representative of the close ties that exists between academia, science, and the business world. Silverstone (1992), asks the question, "How did you come to create the Media Lab?" (p. 26). Negroponte responds, "we found that the kind of communication channels we were working on were very much of interest to telephone companies, broadcast companies, and consumer electronics companies. So one thing led to the next to basically build a media laboratory" (Ibid). The MIT Media Lab and Negroponte are major influences on development through innovative projects such as the development of three-dimensional computer-generated holograms, new computer languages specifically intended for use by young children, personalized newspapers, and intelligent page-layout software for word processing. Projects include such graphics development as a 2,000 by 6,000 pixel display (three CRTs tiled into a single, seamless panel) for presenting layered world news and graphics information (p. 26). They also work on digitizing video frames from old TV shows like "I Love Lucy" to create formats that allow "intelligent" software to create three-dimensional models of each object in the frame. Such processes allow dramatic signal compression and changes to perspective, colorization, adding and deletion of people, animation, and so forth (p. 28). Another project in their "Visible Language Workshop" creates intelligent graphic and design tools that are taught how to make extrapolations that enable the software to imitate a user's graphic style and layout rules (p. 30).

A prime concern for such developmental effort is the cost-benefit ratio of producing commercial images. As Negroponte (1991) writes, "Independence of space and time is the single most valuable service and product we can provide humankind" (p. 108). He is referring to technology in telephone and television communication that will free people from doing business in specific times and places. He concludes that the United States leads the world in advanced television by its use of digital technology and therefore, "First, we must think of images as scalable.... Second, in the long run, model-based image transmission and encoding are better than transmission of pictures alone" (Ibid.) This emphasis on "models" is important because the emphatic stress on cost-benefit ratios leads to a reliance on simple "models" or "snapshots" that can be manipulated as object-oriented, animated digital images rather than traditional analog media such as video or subtle bit-mapped imagery that take longer to transmit. Negroponte wants to dispense with "photographic" imagery and, instead, uses snapshots translated into simple mathematical models of reality. This reflects a need for cost-effective realism in scientific-commercial areas and the entertainment world's desire to distribute cultural imagery effectively. However, for the artist and the art teacher it means software that will be most effective and easy to use with models while bit-mapping techniques are increasingly structured to supplement the modeling.

Wilder (1992a) also relates how the merging of scientific and commercial needs influence development. For example, The National Science Foundation (NSF) and the state of California jointly fund The Advanced Scientific Visualization Laboratory located at the San Diego Supercomputer Center, the influential imaging research facility, commonly known as Vislab. Here they use a Cray Research, Inc. Y-MP8/864 with 2.7 billion floating-point operations per second as well as two other supercomputers, an Intel Corp. iPSC/860 and an NCube Corp. NCube 2. This hardware configuration is incredibly powerful but commercial needs again influence the developers in terms of software and hardware research. The imaging development is primarily for commercial projects such as the ones dealing with problems in the California Department of Water Resources and their need to simulate the pollution flows in the San Francisco Bay area. Similar projects funded by industry and state governments include simulation of earthquake effects on building designs. In short, the industry is motivated by the need for scientific modeling, CAD/CAM (computer-aided design and manufacturing), design and advertising, and special film effects in the entertainment industry. Often, these commercial graphics projects are shown as art in magazines and on TV programs where they comprise a large part of the "good" examples that teach students and the public about digitized imagery. As Palyka (1989) says, "Computer graphicists are basically problem solvers who are thrilled with the notion that they are not limited to just writing about and talking about their solutions to the problems, but can show them off visually too" (p. 53).

The developer's motivation is obvious. As K. S. Nash (1992) explains, new technology such as the *Avid* system is being used by video studios because such systems are the, "key to making money" (p. 94). The *Avid* System reviewed is used by 750 production studios worldwide and it is responsible for such documentaries as *Making Sense of the Sixties* and advertisement spots for Diet Coke and Nike sneakers. Similarly, Del Nibletto (1992), writing about the new Centre for Advanced Studies (CAS), a Toronto, Ontario based research laboratory established by IBM in 1990, says, "two main reasons for the creation of CAS is to bring industry closer to the research community and to move technology faster from research to products" (p. 6). Hildebrand (1992b) notes there have been many questions and negative comments from artists about the relationship between art and computers, but suggests, "nobody can argue with the idea of creating a network to help art dealers better *sell* art created by humans" (p. 65). Hildebrand writes about *Art Co-op*, a company that uses a network of PCs to list about 16,000 titles of limited-edition serigraphs and the like for dealers in the U.S. and Japan. The company will take the orders, check the product, and deliver within 48 hours for a ten percent commission on each work of art. While nobody may find fault with such a use of the technology, it has implications for the art world and the way art is integrated into the culture since art that lends itself to digitization will get the most advantageous distribution.

In another case, an unusual turnaround where artistic initiative led to commercial applications, Zajc (1992) writes about the two year project initiated and carried out by Andrew Wyeth's wife Betsy largely through the help of their Maine neighbor Thomas Watson Jr., the former CEO of IBM. The objective was to develop a computer workstation-based imaging system that included a high resolution scanner with "faithful colour" capability in order to get the artist's work into a format where, "Unlike original pieces and papers, the images won't age over time" (p. 6). This system also allows easy data entry of information about the art works and a quick search of the data base. The Wyeth's employees have catalogued over 6,000 works and the system has been made available to the wider public market. Interestingly, Zajc notes that the system can now be expanded into the "real money market" which is, "insurance industry, government departments, or banks; any organization which needs to archive a wide variety of material in multitasking form" (p. 41).

The most sophisticated software is used for CAD/CAM and this is an important area for new developments and directions in all "draw/paint" software. One estimate is that manufacturing accounted for $228 million of the $1.9 billion imaging market in 1991 and it is projected to be $358 million out of a $2.35 billion imaging market in 1992 (Booker, 1992). Ward (1989) says computer-aided design and manufacturing, "accounts for more than half of all the money spent on computer graphics" (p. 741). In short, CAD/CAM with its stress on engineering and scientific realism is an important influence and the engineer's needs determine much of the development that will be done. Such technical improvements are promising for graphic artists but in such imagery aesthetic value is a byproduct of the commercial value just as the powerful aesthetics of digitized movie effects are a byproduct of the entertainment industry's need for transient novelty and continuous innovation that capture a paying audience for a brief time. In other words, such developments are driven largely by pragmatic concerns. Foley, van Dam, Feiner, and Hughes (1990) are clear throughout their influential text and state bluntly, "It is important to follow the Bauhaus dictum, *form follows function*, lest the user-interface style dictate the capabilities of the overall system" (pp. 430-431). They fail to recognize how the user-interface style is integral to art-making and affects the results in dramatic ways; there is no logical or necessary link between form and function since this relationship changes with the time and place where art as *Art* is made and viewed. Rosenbrock (1990) provides an example of the attitude developers take:

> In social life and in everyday matters, people are treated with the courtesy and respect which society expects. But in technical matters they have to be treated as machines, as causal devices, because these are the only terms in which our science, and our science-based technology, can deal with the world. (p. 155)

Solid modeling is important for scientific views of a physical world that is hidden from other visual methods of analysis; it is used by the entertainment industry in special film effects, arcade games, and virtual environments; and business and manufacturing communities use it extensively. Prior to the 1970s, there was little interest and the, then, state-of-the-art applications in animation, flight simulators, and scientific research on perception didn't see any great need for unambiguous, "valid" solid models; the tremendous processing power required was not considered worthwhile (Stewart 1990). Brown (1989) writes of the engineering community's initial resistance to the overhead required for realistic imagery and how it is gradually being overcome by a recognition of the commercial benefits. Brown cites a representative from the Ford Motor Company who emphasizes how specular reflection of the horizon on a car's surface becomes a key element design that is as important aesthetically as the car's profile. Brown writes, "Clearly, the provision of physically correct full-colour simulations could significantly increase productivity, and it's not surprising that auto developers like Ford and General Motors are at the forefront of research in the area" (p. 17). As Foley, van Dam, Feiner, and Hughes (1990) write,

> Perhaps the most important new movement in graphics is the increasing concern for modeling objects, not just for creating their pictures. Furthermore, interest is growing in describing the time-varying geometry and behavior of 3D objects. Thus graphics is increasingly concerned with simulation, animation, and a "back to physics" movement in both modeling and rendering in order to create objects that look and behave as realistically as possible. (p. xii)

This means a great deal of effort is spent on the development of hardware and software with specific propensities; a predominance of imagery that is easy to make with computer graphics and a lack of imagery that is virtually impossible with this technology. Newquist (1992) provides examples in solid modeling and virtual reality: VPL Research, Inc. data base administrators use virtual reality headsets to "walk" through their databases, telecommunication companies such as Tokyo Electric Power and U.S. West use sophisticated goggles and gloves to manipulate 3-D computer-generated network grids, the University of North Carolina does molecular research with specialized gloves so the researchers can grab molecular structures, and various companies use their electronic gloves and head sets to let clients manipulate colorful 3-D architectural images (e.g., designs of a new European office complex, the city of Berlin's new subway, University of North Carolina's Sitterson Hall, kitchen layouts in Matsushita stores, etc.). Newquist also explains how Stanford Medial School and NASA uses virtual bodies so medical students and doctors can use gloves and headsets to experiment on simulated patients with new procedures. Similarly, J. Nash (1992) provides an example of Robodoc from Integrated Surgical Systems (currently being tested on dogs with FDA approval for use on humans expected shortly). This system uses CAT scans to generate simulated three-dimensional computer images which are used with sophisticated operating-room robotics to make hip implants. The system controls drilling of the hole in the femur while a surgeon holds a control device that allows him or her to intervene if necessary. The world of virtual reality is considered as the area of greatest potential for mass entertainment and such new scientific simulation technology is appearing in arcades every day. If artists use such software, they work in virtual environments designed primarily for science and commerce where a limited notion of reality dominates the world-view.

Computer graphics increases the efficiency of the image-maker in certain ways through its ability to make popular and commercial art that is accessible and efficient for mass media and scientific illustrations. Techniques such as scaling, perspectives, wipes, or mattes are familiar from painting, drawing, photography, and film but these effects can be employed within limited parameters in computer graphics by a trivial push of a key or a click on an icon. However, computer graphics is not just another way of making an image that is communicated with as much transparency as possible. Like other electronic media, such as telephones, radio, and television, computers do more than augment the human senses and extend the world-view of time and space. Digitization can be used to save time and money but the images are not the same as those that would be made in traditional media. There are many uses for products such as Delta Tao Software's *Monet* that can make a photograph into a "Monet" painting with a key stroke but such imagery is a pale imitation of oil paintings that rely in part on texture, canvas, and size. With computer graphics, imagery is both empowered and restricted by the reliance on explicit knowledge that can be reduced to discrete bits of data suitable for computer storage, manipulation, and retrieval through algorithms that follow strict formal operational rules. This provides tremendous power for computer graphics but it rules out art-making that relies on subtle, intuitive manipulations. This bias is blatant in all computer graphics technology.

In other words, computer graphics is a powerful tool and medium for image-making but it is inherently biased for limited, structured form and content by its development in the scientific-commercial sector where aesthetic value is secondary and imagery is primarily intended to carry information or light entertainment for a public that demands novelty in content and form, progress in technical effects, and increasing access to the image. Since digitized imagery is defined and manipulated by simple algorithms, it assumes a formal quality that is necessarily part of techniques such as solid modeling, fractal models, and ray tracing. Such techniques make it easy and cost effective to pursue image-making that is meant to be distributed or animated since the mathematical definitions can be altered with simple formulae. The bits and bytes of digitized imagery can be decomposed, sent, and reassembled with ease, speed, and accuracy. These inherent qualities are necessary in order to provide cost effective communication of imagery within a variety of media. They are also necessary in order to provide added interest to imagery which can appear stiff, formal, and uninteresting without such manipulation or animation. But, as Nadin (1989) suggests,

> It is time to examine what we address as computer art and to try to understand why, despite expectations (some very high) and tedious work, despite major investment (easily approaching the billion dollar mark and exceeding any other investment made in art), and despite enthusiasm, the results have been rather minor. (p. 43)

The "Art" in Computer Art

Broadly speaking, the Western concept of *Art* includes the diverse objects and expressions that are categorized as "art" by both common usage and art experts who rely on historical precedents and current art theory. Within this concept are many of the objects, expressions, and ideas individuals attend to aesthetically; the things they attend to, at least in part, for the pleasure of the engagement itself because of an unarticulated "rightness" or "form" over and above attention to the individual parts that comprise the whole. However, individuals also engage "non-art" such as natural objects or scenery aesthetically and the definition of "art" is largely determined by society. Baynes (1990) suggests art is as important a cultural invention for defining human society as writing or agriculture and adds,

> From the first, the things people made and used had to be beautiful and have personal and social meaning. In the hands of men and women, tools and materials do not only make practical things, they also always give shape to observations, ideas, and fantastic imaginings. (p. 7)

A digitized image must be related to Western culture in order to determine how it is valued. The term, *Western culture*, defines the loosely woven web of beliefs, traditions, rituals, and purposes that form the characteristics of Western society (Barzun 1989, Nye 1970). *Culture* is synonymous with *society* in an anthropological sense but, in the thesis, *culture* refers to the arts including vernacular arts such as photography, film, radio, television, popular music, home video, comics, magazines, paperbacks, advertising, and design. The arts are artistic expressions of a society distinct from economic, political, or religious expressions. *Fine Arts, The Arts,* or *High Culture* are terms used interchangeably to define a select group of the arts that are commonly regarded as a primary source of Western artistic heritage. These terms usually encompass music, poetry, painting, sculpture, architecture, dance, literature, and drama. Fine art, art valued in part for its ability to provide aesthetic experiences, is the traditional basis for evaluating art that provides light entertainment, sells products, or presents socially useful information. This role of fine art has been eroded in part by the commercial merging of all areas of the modern art world and by increasing digitization that makes all art, including fine art, into useful objects. Furthermore, while all art is defined by its aesthetic value to some extent, there are always other non-aesthetic values involved in the culture-bound context of evaluating art; values determined by the society at large. Thus, computer art must be defined in terms of both an aesthetic value derived from its ability to engage individuals aesthetically and as a socially significant phenomenon. The *art world* is taken to be the commercial and non-profit organizations involved in making and distributing art and artistic services in Western culture; a *fine art world* for *high culture* and a less focused structure for *popular* and *commercial arts* that reside primarily in the mass media.

As Baynes (1990) points out, there is a shared human propensity to make objects that are valued for more than utilitarian functions. However, exactly how art and society are related is controversial. For example, Mulgan and Worpole (1986) propose, "As a concept art's primary role is ideological: to embellish the pleasures and self-respect of some (usually the metropolitan elites) and to downgrade the pleasures of others" (p. 114). Or, Barzun (1973) suggests,

> it is clear that if art has importance, it is because it can shape the minds and emotions of men. It can enlarge or trivialize the imagination. If it can do so much, it affects the social fabric as well as individual lives for good and evil. (p. 17)

Art, in the broadest sense, is valued both as commodity and concept in Western culture. Just as literacy is valued as a model for intelligence and as a primary means of understanding the social and physical world, knowledge of fine art has traditionally been valued and used as a measurement of cultural accomplishment. Art is also seen as a social concept; a means of communicating social values and ideas. For example, Chalmers (1987) considers art to be an important means of changing or maintaining cultural values such as religious beliefs, social status, or political ideals. Within this view, art has an economic function and it will also be important for leisure and play activities that shape the culture. Chalmers sees these roles as an important part of art that does not deny art's aesthetic role in its capacity to decorate an environment. Chalmers writes,

> If art has no communicative role, then it cannot maintain or change cultures or even be said to be enhancing. If we, as art educators, are to produce artists or art consumers who can see art's function in society, then we need to consider the cultural foundations of art and broaden our definitions of art to include the cultural artifacts of all cultures and subcultures. (pp. 4-5)

If we ignore the way digitized imagery replaces holistic imagery for the moment and see all art primarily as means of communication, digitized imagery offers distinct advantages and opportunities since it can be easily, quickly, and cheaply edited and communicated. That is, digitized images intended to serve as communication, as a part of cognitive activities engaging a unique symbol system, are valuable because they are inherently more structured than analog imagery. Furthermore, in pragmatic terms, digitization allows access to analog images that are more exclusive in their original media and socially oriented uses of art can be accomplished in new cost-effective and democratic ways. Thus, as a way of maintaining or changing cultural values, a digitized image is valuable because it can be readily adapted to current social needs and widely shared. The loss of analog subtlety in imagery and the limits of formal expression that come with digitization are not to be ignored but they do not negate the advantages for communicating art intended to influence viewers who are widely dispersed and diversified. Thus, as a social phenomenon, ignoring the cultural and technological bias for scientific-commercial form and content, digitized art appears to justify the enthusiasm seen in a great deal of the writing associated with the narrow view.

<u>Aesthetic and Non-aesthetic Value.</u>

Artistic value in Western culture is defined by taken-for-granted principles (Wolff 1981, 1993; Zolberg, 1990). Primarily, these include the notion that valuable artworks are unique objects such that copies can be traced to a unique work and the assumption that all art is the creation of a unique artistic genius. This is presented as a view, a fact, an opinion, or a convention at times but it is the foundation broadly shared by many members of Western culture. These cultural principles are questioned by contemporary writers such as Wolff but they are assumed by most consumers of the vernacular arts. The ranking of art in the fine art world also relies on these principles and the more unique a work is, the greater its value. Similarly, the more an art object is associated with a unique artist who is attributed with skill and insight not shown by others, the more value it is given. The term, *aesthetic value*, traditionally defines the value Western culture attaches to art based on its ability to provide aesthetic experiences. For representational art, it is often assumed that "form" or "structural-aesthetic qualities" provide the aesthetic value which can then be distinguished to some extent from "content" or "messages" (non-aesthetic elements). The pure content is irrevocably part of the overall value but, outside the commercial art world, it does not depend on the artist or the uniqueness of the art in the same way as form and thus, in the traditional view, content is a secondary value. Many artists, critics, historians, aestheticians and other professionals rely on these principles to shape conventions and share this foundation with a lay public and a wider cultural structure that simply assume this is the case.

Digitized imagery that exists as pure numbers defies a notion of uniqueness. There is no original, unique image that is copied and distributed widely through the mass media since the mass product is the digitized image itself through its pure numbers and algorithms. Similarly, digitized images are often derived from existing images, many good images are widely and anonymously distributed, and all digitized images are ready for further manipulations. It is therefore the antithesis of traditional fine art yet, at the same time, it is the most important new imagery in the vernacular arts where scientific-commercial bias is not viewed as a delimiting, negative characteristic. The nature of digitized imagery as pure numbers and algorithms that manifest themselves to the image-maker as pixels makes it scientifically simplistic with a propensity for being widely copied and easily distributed. *Webster's New Collegiate Dictionary* (1981) defines the word "trivial" as: "1: commonplace, ordinary 2a: of little worth or importance b: relating to or being the mathematically simplest case" (p. 1242). Without necessarily making a pejorative remark, we can say digitized imagery is trivialized, first, because it is commonplace imagery for students heavily involved with popular media and, second, because it is the mathematically simplest case by definition. The trivialization of digitized art through its mathematical basis and commonplace location in the art world is reflected in a widely-held understanding that situates it in Western culture as popular and commercial art with relatively little artistic value.

There is no logical reason for suggesting digitized images have less aesthetic value than analog images. Presenting an unknowing viewer with two matted, framed pictures where one is a Dürer etching and the other a digitization of the etching made with a high resolution scanner and a 1200 dpi printer with good quality graphics paper will not allow the viewer to tell the difference. Yet, the digitized image is generally considered inferior because of non-aesthetic qualities that are related to the historic influence of Dürer as an "artistic genius" who made a significant contribution to Western art. In other words, the original etching is regarded as a more valuable work because of non-aesthetic values attached to Dürer's art by the art world which thrives on the economic advantages of dealing in unique art.

While there is no logical reason for digitized images to have less aesthetic value than analog images, "form" is, in part, a determinant of the aesthetic value associated with digitized art. Engler (1990) proposes that, "aesthetic concepts, like any other concepts in science, must find their representation in mathematical forms and relations, whatever their degree of abstraction" (p. 28). His view suggests that *simplicity*, *symmetry*, *elegance*, *harmony*, *order*, and *coherence* lead to *unity*. Most computer art reflects the commercial software's bias for a "formal" mathematical quality that is reinforced by computer graphics developers who consciously separate concerns about content and formal qualities; they only intend to facilitate form within the limitations of the technology as determined by those who pay. This is apparent in "low-end" "draw/paint" software and thus an inherent bias for formal realism and geometric shapes dominates the type of software used in most art rooms. As a result, the form of digitized images made by students using commercial software compared to analog images made with media such as pencil or paint, is often simplistic both in structure (the physical characteristics that include shape, size, materials, and method of making) and in the theoretical concepts within visual elements (seen as points, lines, shape, texture, color, and so forth). For example, some digitized art retains the overt stereo-typical scientific-commercial characteristic such as symmetry, repetition, and simplicity. And, as Nadin (1989) writes,

> Computer-generated art and electronic music are interesting, and some works are provocative in their novelty. But once we have seen a computer graphic image or listened to a computer-generated piece of music, it seems that we have seen and heard them all.... As opposed to works of art that look better the more we look at them, electronic art seems to exhaust itself at the first encounter. (p. 43)

There are also more mundane influences. For example, if we view digitized imagery in terms of physical characteristics we see that it is largely limited to imagery made on a small screen and it is likely to be printed on paper and used for pragmatic ends. Furthermore, it usually illustrates ideas or describes situations. Even the digitized imagery that is primarily intended to provide aesthetic experiences is restricted by technology and the best examples are found in art magazines and on CD's. In other words, digitized imagery is not easily incorporated into the fine art world but it is the perfect means of making imagery for mass media where it suits a wide distribution of cartoons, illustrations, popular films, and so forth; is restricted by its physical characteristics, theoretical concepts, and the cultural context. Thus, the simplicity of form in much of the digitized imagery combines with the restrictions of ephemeral computer screens, small sheets of bond paper in black and white printers, and the inset squares on contextual pages of magazines or books to impoverish many digitized images.

Another influence on the value of digitized art comes about from the way the technology is widely used to incorporate other imagery through frame grabbing or scanning. That is, both "good" analog and digitized imagery becomes a facile source for further manipulation and distribution. As knowledgeable students look at digitized images, they are subtly made aware that they do not usually have the same financial, historical, or collectable value as an oil painting or copper plate etching. They know that digitized images can be cloned and widely distributed without loss of originality and they are limited and defined by the latest computer technology. Even though it may take as much skill, insight, and effort to make good digitized images as it would to make good oil paintings; the finished product reflects a totality that is perceived to be less valuable than the oil painting because it is so readily accessible and easily commercialized. Once digitized, any image is easily copied and distributed. Because it is so easy to change images and to scan them from other media, there is a very strong tendency to use the same images again and again in various permutations of size, output medium, color, and context. This makes many digitized images, especially those with a wide appeal, derivative and anonymous.

The emphasis in the mass media is on images that are as close to current standards of reality and popular artistic form as possible. Since both the developers and the users share a passion for the same ends, it means both form and content become a reflection of mass culture; they reflect current cultural values and social needs. Any digitized image that holds public interest for a short period of time quickly becomes trivialized through rampant imitation and tagged with a "throwaway" label. It is no wonder some educators are disturbed by a plethora of digitized *Mona Lisa* images, *Santa Clause* pictures, and trite icons of popular art that show an overt lack of traditional aesthetic appeal yet attract an appreciative audience in the classroom, home, and office because they can be readily changed to suit any need for adornment or used with text as posters, banners, or greeting cards (Greh 1990). The vast amount of digitized imagery and a drastic increase in speed and growth in the way it is made and distributed make their own impact. The result is a trivialization of art images experienced in a context dominated by productive stress and a casual relationship between the art and uncritical, uneducated viewers.

Popular Art and Mass Culture.

Most digitized images students like appear in the mass media or as non-aesthetic, usually scientific, images and their value in such contexts is undeniable. Scientific illustrations and simulations made with computer graphics can be created more cheaply, more quickly, and are they are clearer than before. In a large number of cases, scientific and technical illustrations that originate as pure data were not possible in other media. Similarly, computer animation cartoons and special film effects were initially used because they were cheaper to make but now technology is so powerful it allows effects such as "Morphing" which are almost impossible with traditional special effects. These powerful uses of computer graphics are prominently featured and the practical value manifests itself in homes, schools, and workplaces. Without a realization of how such images are made and how they present a strong bias, students will simply accept and appreciate them without an awareness of the alternatives. Some digitized illustrations rival the best drawings and the technology presents valuable opportunities for both amateurs and professional artists who manage to avoid the simplistic form that is so prevalent with uncritical use of commercial software. However, classic images such as the *Mona Lisa* and Van Gogh's self-portrait or popular images such as *Mickey Mouse* and other Disney characters are encountered in many media and display contexts with variations of size, color, and so forth until individuals no longer react to them with any emotional enthusiasm or see them purely as a stereotype.

This means that the traditional, culturally determined evaluation-distribution structure associated with collectible fine art originating from a unique artist is undermined and traditional art collectors and dealers cannot easily incorporate the economic reality of cheap, non-singular digitized art works. The context of how and where we view an image along with the material worth of the art object are two important external aesthetic criteria for establishing the value of an image. The same image viewed in a prestigious museum or on a sophisticated art gallery wall is imbued with a dramatically different value than the exact same image placed as an advertisement within a popular magazine. Such a cultural value system means expectations vary when individuals look at images based on their location since it is generally assumed that there is a set of culturally approved expert assessments involved in the process that places images. There is little economic incentive for the fine art world since the pure numbers that constitute digitized imagery make copies cheaper and more available than other fine art. Therefore, virtually all digitized images are defined as popular art since they are so widely used and highly valued in the vernacular arts and the mass media.

Western popular art is an eighteenth century construct that came about during a time of great social change and developments in image duplication and distribution techniques; an art that suited mass production technology and corroborated values and attitudes familiar to a widening homogeneous audience. Thus, the technological characteristics of mass media and the taste of mass audiences who valued light entertainment and useful instruction above aesthetic experiences was the major influence on successful new content and technique as the Western art world began to distinguish popular arts (in utilitarian or social terms) from fine arts (Nye, 1970). This distinction relies on several traditional categorizations. For example, there is a long standing idea that we can distinguish inspired fine art from crafts where ends are distinguished from means; the object is preconceived or modeled before the art-maker begins a prescribed art-making process. Similarly, it is generally assumed that popular arts can be separated from serious arts. This difference is usually defined as a contrast between fine art that provides deep, profound aesthetic experiences and inferior popular arts that provide fleeting, superficial aesthetic pleasures. Such separations are often clearer in pragmatic terms and they are often seen through the way fine art such as paintings or sculptures involve expensive materials, imposing formats, formal exposure in galleries and museums, and culturally important subjects while popular arts and crafts are usually less costly, less monumental, shown in the market place and mass media, and more mundane or prosaic in form and content. Thus, terms such as *fine* and *popular arts* show what segment of the population art is aimed at and what tastes are satisfied; they distinguish categories by the kind of taste art satisfies and imbue art with comparative artistic value.[8]

In modern society, art imagery is shared by all economic levels through a mass media that is no longer associated exclusively with lower class taste. In effect, the strong social impact of mass media incorporated all types of art into electronic networks that distribute imagery throughout the world. The lines of distinction are blurring because fine art is used in commercial art and there is increased access to all art through laser disks, videos, television, books, and magazines. Artistic value can also change. Popular illustrations and posters end up in museums while large, elaborate oil paintings and stone statues are scrapped by later generations; furniture, crafts, utensils, and so forth become fine art while fine art is discarded or relegated to history. As Clignet (1985) writes all cultures have a tendency to, "contrast individual works, genres, and disciplines in terms of their 'durable,' 'transient,' or 'rubbish' properties.... Because these categories are social constructs, the placement of individual works, genres, or entire disciplines in either one of these categories cannot be stable" (p. 129). What must be added is that such changes are best understood through critical evaluation from comprehensive cultural perspectives. Theoretically, as noted earlier, there is no reason for digitized imagery to have less aesthetic value than analog imagery if it is not driven by a scientific-commercial bias for limited form and content. Digitized imagery as popular art appeals to a large number of people and it is readily available to them through the mass media. Furthermore as Gans (1974) argues, there is no reason to assume that, because popular art is organized primarily for profit (also the case for fine art), it always produces standardized, mass produced objects with inevitable loss of individual expression, skills, and values. The fact that relatively few anonymous artists originate imagery which is widely distributed to a mass audience does not in itself lessen aesthetic value. Gans writes, "popular culture reflects and expresses the aesthetic and other wants of many people (thus making it culture and not just commercial menace).... all people have a right to the culture they prefer, regardless of whether it is high or popular" (p. vii).

The Criticism of Popular Art.

Proponents of the narrow view are almost uniformly optimistic about the use of the new technology associated with computer graphics. Similarly, populist writers, such as Naisbitt (1990) see a new Renaissance of the arts through new technology sponsored by an affluent information society. However, as shown earlier, there is a powerful, ubiquitous cultural influence, a bias for form and content associated with the scientific-commercial world. Critics who address this bias directly or indirectly by commenting on the overwhelming influence of the popular arts in the mass media are rarely clear about their concerns for commercial software or digitization as such. Instead, they comment on a generic negative influence on the young through overexposure to art (Fruger, 1983; Barzun, 1989) or decry the new "computer art" as uninspired, boring, dreadful, or ugly junk (Nadin, 1989; Smith, 1989; Ellul. 1990; Roszak, 1986). Other writers, for example, the French sociologist Pierre Bourdieu, and Frankfurt Critical School of neo-marxist theorists such as Max Horkheimer, Theodor Adorno, and Herbert Marcuse, take a far more philosophical approach and present an overtly pessimistic view of mass media and associated technologies. These views provide a framework for much of the current criticism of the popular arts that can be extended to computer graphics in schools.

Horkheimer, Adorno, and Marcuse suggest that modern industrial society is dominated by capitalist entrepreneurs, technicians, and entertainers who rely on new technologies that threaten individual freedom by limiting expression, including artistic expression, through a perceived need for efficiency, rationality, and technical expertise. They suggest modern industrial systems of production make people more passive within hierarchical society where they are increasingly threatened by complex forms of enslavement that are legitimated by technology; the masses are made comfortable by popular art within an inherently unjust social system. Marcuse (1966) defines modern technology as propaganda and says that the overwhelming power and success of such technology effectively undermines any interest in critiques of the negative aspects of technological development; "as a technological universe, advanced industrial society is a *political* universe, the latest stage in the realization of a specific historical *project* - namely, the experience, transformation, and organization of nature as the stuff of domination" (p. xvi). Marcuse sees high culture as an instrument of oppression and mass culture as inimical to democracy since there is no distinction between, "the mass media as instruments of information and entertainment, and as agents of manipulation and indoctrination" (p. 8). Within this view, capitalist ideology and its domination is seen as constitutive of the form and content of modern technology itself and this technology provides the framework for capitalist ideology that controls the individual's life. In Marcuse's view, individuals become one-dimensional in their behavior and thinking while technological processes have become overt means of domination and exploitation.[9]

Similarly, Horkheimer and Adorno (1972) argue that the modern culture industry incorporates new technologies to make art into commodities suitable for a capitalist system. In Adorno's (1991) view there is continual degradation of traditional values since the culture industry, "intentionally integrates its consumers from above. To the detriment of both it forces together the spheres of high and low art, separated for thousands of years" (p. 85). The shift is based on economic power shifts so profound that popular arts, "are no longer *also* commodities, they are commodities through and through. This quantitative shift is so great that it calls forth entirely new phenomena" (p. 86). Popular arts are seen as demands evoked and manipulated by the insidious cultural industry and "The so-called entertainments, which have taken over the heritage of art, are today nothing but popular tonics, like swimming or football" (Horkheimer, 1972, pp. 289-290). For Marcuse, Horkheimer, and Adorno, digitized imagery is the ultimate seduction of the proletariat masses who are exposed to more popular arts than they have ever been before and are increasingly invited to participate in image manipulation through firmly delineated parameters of a biased technology that dominates image-making in the vernacular arts.

Bourdieu (1990) provides another critical comment on traditional views of art as expression of emotion or symbolic forms of intuitive knowledge. Bourdieu denies any "natural" basis for human ability to appreciate art and says all art appreciation is based on a conscious or unconscious cultural deciphering by those who have the means of decoding socially constructed artwork. Bourdieu uses photography as examples and this offers insight into the way computer graphics is placed as art. He suggests that, unlike art media such as drawing or painting, where there is an overt demand for attention to historical-professional values and standards, photography is accessible to all with little or no need to care about cultural standards, especially not the cultural elite's standards. Photography, like computer graphics, is available to everyone and the push of a button quickly executes predetermined, technologically biased actions that result in imagery conforming to generic standards. In both cases, technical processes and discontinuous operations place a distance between image-maker and art which is a contrast to the immediate, sensual link that exists when drawing or painting. It is always necessary to accommodate rules imposed by machines that automate some aspects of image-making and impose unavoidable bias. As Bourdieu says,

> On the one hand, like any practice that brings artistic values into play, photography is an opportunity to actualize the aesthetic attitude, a permanent and general disposition; but on the other hand, precisely because photographic practice, even in its most accomplished form (and *a fortiori* in the form that it is given by every amateur), comes very low in the hierarchy of artistic practices, subjects feel less imperatively obliged to exercise their aesthetic sense. (p. 65)

The camera with its selected view of time and space is an example of how technology enters a culture. Major manufacturers determine what lenses, film, and printing paper will be readily available and smaller competitors follow de facto standards because of economic advantages. These constraints and cultural values of photographs from mass media determine what is photographed and how it will be done. Artists who want to break the conventions and explore new avenues are severely hampered by such bias because there is a need to move away from the standard thirty-five millimeter camera lens and the attached conventions of contemporary photography as it is practiced by the general public. This is also the case for computer graphics when approached uncritically by young students. On the one hand, students want to make the same type of imagery they see in the mass media and they are encouraged to do so by the bias of the technology. On the other hand, computer graphics is so firmly associated with the vernacular arts that it frees students from the formal aesthetics associated with the fine arts. Many digitized images follow photographs by being anonymous and the marketplace does not make a distinction between attributed images and the well-realized works of unknown individuals. There is little price difference commanded by artists of varying reputations and they are always low compared to prices commanded by painters and sculptors. Thus, graphic artists like photographers rely on a body of work to show their abilities, their masterpieces are exemplars, and they are represented in the fine art world through a few pieces that demonstrate a type rather than uniquely realized works from a prominent artist. For example, there is no outstanding exemplars of the art of James Blinn (originator of Blinn curves) or B. Mandelbrot (originator of fractal images) that provide an exemplar for their art work but there are numerous examples of their unique "type" of art work both by the artists themselves and by other image-makers who use the new techniques. This partially accounts for the way computer graphics is placed in the art world and valued by students.

The difficulty with Bourdieu's view is that he perpetuates the notion that popular art is aesthetically inferior. He suggests, "subjects feel less imperatively obliged to exercise their aesthetic sense" but he also assumes that "sense" is limited by the ability to decode social constructs. Constant reference to the best examples as fine art and recurring allusions to popular art that is the most mediocre fails to acknowledge the aesthetic value of popular art which is not always dominated or impoverished, as history shows. There is no denying the interests of the art world where economic values predominate at the expense of aesthetic values in both fine and popular art. There is also no denying the great inadequacy of form in much popular art, the most common avenue of criticism. However, this does not mean there is no legitimate popular aesthetic. This is also the case for Horkheimer and Adorno who condemn the modern, media-saturated world without seeing the value of art, art-making, and thinking about art that is not always serious or intellectual; like Bourdieu, they fail to acknowledge that technical perfection and aesthetic values can be found in popular art and computer graphics.

Marcuse, Adorno, and Horkheimer show how popular art can be viewed as an insidious influence. Similarly, Bourdieu shows how popular art forms such as photography or computer graphics can promote art forms that are assumed to have less artistic value than other art. Such views are in stark contrast to those of Chalmers (1987) and others such as McFee (1988) and Bersson (1987) who believe that popular art facilitated by computer graphics and other new technologies could be valuable means of communication and useful social change agents. The thesis does not justify any of these views in depth, such an extensive argument being outside the scope of the thesis, but digitized imagery is inevitably linked to popular art and teachers who use computer graphics must recognize the value of such art. Toulouse-Lautrec and other artists have proven that such narrow definitions don't always stand up over time and, as Gans (1974) noted, popular art has value for those who get enjoyment from it. Critical views of popular art do not support a suppression of computer graphics in schools. Quite the contrary, each view could suggest educated access to the technology is desirable. Ultimately, the value of a digitized image as art must be found in the unity of content and form. In short, as Marcuse (1977) correctly states,

> The critical function of art, its contribution to the struggle for liberation, resides in the aesthetic form. A work of art is authentic or true not by virtue of its content (i.e., the "correct" representation of social conditions), nor by its "pure" form, but by the content having become form. (p. 8)

Digitization as Progress

Computer graphics seems to be revolutionary at first glance; the, "most civilized and human tool ... we have embraced rapturously" (McCorduck, 1985, p. 15). Compared to cave paintings shared by a few tribal hunters, the transmission of digitized images via satellites in geosynchronous, permanently fixed orbits 22,300 miles above the Earth is progress. Images are copied, altered, and communicated faster, more easily, and more accurately than before. However, this does not mean that computer graphics is revolutionary progress in art or art-making as some proponents suggest (Youngblood, 1989a; Malina, 1989; Goodman, 1987; Clignet, 1985; Becker, 1982). Improvement in techniques and tools may not result in improvement in form, content, or aesthetic value. For example, modern power tools could have made Michaelangelo's sculpting easier, he might have made many more sculptures in his time or completed some of his monumental projects. However, he is just as likely to have changed his approach and produced impoverished images without aesthetic appeal because power tools allow rapid progress that may eliminate contemplation and commitments generally associated with each fatal tap of the mallet. As Dewey (1934) writes, "while there is not continuity of repetition in any aesthetic art, neither is there of necessity, advance. Greek sculpture will never be equaled in its own terms, Thorwaldsen is no Pheidias" (p. 143). Art cannot be said to progress just because it changes or more people have access to it. It is meaningless to say Leonardo's brushes and paints were better than materials used by Paleolithic artists or that they were not as good as Andrew Wyeth's modern art supplies or James Blinn's computer.

Artists often use new technology to make art because it allows them to achieve new expressions and to explore the relationship between perception and illusion in interesting and novel ways. All art techniques are technology-bound to some extent and there are numerous examples of new technology leading to new art and more availability of both new and traditional art.[10] For example, lost wax (*cire-perdue*) bronze casting shows how bronze Shang sculpture was made possible through the techniques and material cannon makers used. Similarly, Minimal Art reflects artistic use of synthetic, high-tech products that allow smooth, geometric forms. More recently, Pop and Op art movements show how the relationship between art and science manifests itself through opportunities offered by new industrial technology. Op Art follows experiments in color patterns and visual response to optical illusions while Pop Art shows the influence of commercial art. And, during the 1960s, Kepes and others within the Art and Technology movement continued the exploration through opportunities for art-making with new photographic techniques that gave access through high-tech optics. As Lucie-Smith (1970) says, artists have always been fascinated by new materials and technique: "we find young sculptors experimenting with direct welding or with fibreglass. It would be illogical if they didn't borrow, as well as the techniques of industry, a good many of its modes of thought" (p. 41).

It is necessary to clarify the way "progress" is related to aesthetic and non-aesthetic values of digitized images; necessary to distinguish technological progress, which does follow scientific progress, from progress in art in order to clarify the assumptions in the narrow view that computer graphics represents significant advancement in art-making and progress for art and art education. As Gombrich (1972) writes, "we must not forget that art is altogether different from science. The artist's means, his technical devices, can be developed, but art itself can hardly be said to progress in the way in which science progresses" (p. 196). Similarly, Kuhn (1977) notes that Picasso's painting did not simply displace Rembrandt's work in the public's eye and "Masterpieces from the near and distant past still play a vital role in the formation of public taste and in the initiation of many artists to their craft" (p. 345). Kuhn astutely adds,

> This role is, furthermore, strangely unaffected by the fact that neither the artist nor his audience would accept these same masterpieces as legitimate products of contemporary activity. In no area is the contrast between art and science clearer. (Ibid)

Traditional art-making technologies such as painting or ceramics relied on techniques that were partially absorbed and hidden so that art-makers and viewers were unaware of the technology. Therefore, technological progress was not always reflected in the way fine art changed and other cultural factors were more apparent. However, Thomas Kuhn's theory of scientific revolution involving a paradigm shift has been explored by Becker (1982) and Clignet (1985). Both recognize that art is changed by the introduction of new technology and conclude that, if technology is applied science, technology must also change discontinuously. Furthermore, if art follows technology, it too changes discontinuously.[11] Clignet writes,

> Like their scientific counterparts, artistic revolutions rarely take place randomly at various points of the logistic growth of one paradigm. This logistic growth, which refers to the amount of time necessary for a paradigm to reach a visibility twice as large as the one it had at the time of its emergence, can be measured in terms of changes in the number of (a) artists committed to its dominant traits, (b) the works of art of these artists entering in the public domain, (c) the reference made to these works in catalogues, books, articles, exhibitions or even in other works, and (d) the size of the audience attracted to these works. (p. 89)

Becker, writing about impressionism and cubism, says, "Artistic revolutions make major changes in the character of the works produced and in the conventions used to produce them.... Audiences had to learn to respond to unfamiliar languages and to experience them aesthetically" (p. 305). Clignet suggests Duchamp's *Nude Descending a Staircase* and Balla's *Dynamism of a Dog on a Leash* were new explorations of objects in time and space and writes, "Regardless of the rhetoric artists use to that effect, all these changes are revolutionary because they alter the meaning of the distinction between 'art for art's sake' and commercial art" (p. 140).

Art-making and technology are irrevocably linked and changes in techniques are often influenced or directed by new technology such as computer graphics. Because of digitized imagery's intrinsic nature and the ephemeral quality of the pure numbers that alone constitute an image, progress in technology literally translates into "better" images, especially in such areas as animation and solid modeling, and there is progress in the image quality unlike other types of art media where imagery tends to be placed in time and space through its physical manifestations. As Palyka (1989) writes,

> At each major conference the participants expect better and better renderings of clouds, trees, fire, or what ever object they feel is the most difficult to render at the current stage of technological development. They fail to see that art does not get better each year. It certainly changes, but it does not necessarily improve. (p. 52)

Computer graphics technology follows a notion of progress like that associated with science. Greater memory, speed, and storage allow past imagery to be displaced by improved imagery; that is, better realism, animation, and so forth. Even the viewing of an image on a monitor with better or wider color capacity can improve its aesthetic qualities and, similarly, a new printer in the art room with higher resolution capacity will represent progress even though the pure numbers that define the image remain unchanged. Each new technique is progress for the scientific-commercial world and new hardware and software make older imagery and techniques obsolete in the same way new telephones and television sets constantly make older models obsolete. Because digitized image qualities are closely bound to the hardware and software, older images are devalued along with older technology. The inventions of new mass print technology, the development of formal perspective in painting, and the introduction of digitized images shift artistic values as Clignet points out but as Bailin (1988) argues, there is no indication that such innovations are revolutionary in the way Clignet suggests. Even "styles" or genres of painting are not revolutions as such. New styles are always continuations of, or rebellions against, established styles.

Kuhn (1970a) defines a paradigm as a community bound together by several common elements such as education and apprenticeship. Computer graphics developers are a community in this sense and, as Kuhn says, "achievement was sufficiently unprecedented to attract an enduring group of adherents away from competing modes of scientific activity. Simultaneously, it was sufficiently open-ended to leave all sorts of problems for the redefined group of practitioners to solve" (p. 10). He limits the definition to change, "involving a certain sort of reconstruction of group commitments. But it need not be a large change, nor need it seem revolutionary to those outside a single community, consisting perhaps of fewer than twenty-five people" (pp. 180-181). And, "transition to a new paradigm is scientific revolution" (p. 90). Kuhn (1970b) also defines the shared symbolic generalizations and exemplars that define a paradigm: symbolic generalizations are, "expressions deployed without question by the group which can be readily cast in some logical form" and exemplars are, "concrete problem solutions accepted by the group" (p. 463). As Rothen (1988) notes, binary arithmetic, preferred analogies, and exemplars in academic texts and journals about computers show how developers share symbolic generalizations, models, and exemplars that define this technology. Thus, digitized imagery is a paradigmatic shift from analog imagery in the way Kuhn defines such change and Clignet suggests but that does not mean it advances art, art-making, or art education. Digitized imagery presents irreversible progress for vernacular art-making where the ability to easily, accurately, and quickly access, copy, and distribute images is important. However, there is no advancement of aesthetic value but, rather, progress of non-artistic imagery primarily as a means of providing improved communication, information, and viewer interaction.

Kuhn considers scientific innovations as necessities that result from gaps between problems faced by researchers and inadequate responses. This gap leads to discontinuous change that breaks the continuity of new theories and technologies with the antecedents; discontinuous to the point where scientists are forced to make a gestalt switch. Thus, scientific revolutions are said to be contingent on simultaneous changes in the way phenomena are defined and the development of appropriate tools for analysis. However, this is not the case for digitized art images which were incidental by-products of computer technology development. Here, the tools of analysis were developed independently from specific artistic problems and art is changed through the interaction of social groups and the economic advantages that are presented. These groups include the artists who explore new materials such as acrylics and viewers or patrons who find innovative high-tech works both interesting and profitable. Art-making generates problems solved by ingenuity, as demonstrated by photography, but other innovative developments result from artists taking advantage of new commercial technologies. This is the case for digitized imagery which did not come about as a response to artistic problems, not even as response to problems in the vernacular arts where there were revolutionary changes in Kuhn's terms.

Kuhn's theory does not account for the technological and artistic changes in pre-scientific times and the ways both areas continue to evolve outside the areas that are considered science. There are many instances of technological change that are not based on theoretical knowledge. This is particularly so where innovative artists refined and developed new tools to suit their needs. In other words, without stipulative definitions, technological artistic advances could be seen as evolutionary rather than revolutionary. The most important difference between a notion of revolutionary change in science and such change in art is not simply a matter of establishing continuity or discontinuity from one phase to another. It is the fact that scientific change is usually associated with progress while there is no such possibility in art. Artistic revolutions are reversible, partial, and temporary in nature. They co-exist with the art styles of the past and present; new ways of making and seeing art are additions to a constantly changing repertoire that does not follow a linear progression rather, as Bailin (1988) notes,

> new styles add new ways of seeing and portraying to our repertoire. They add new possibilities, whose value is a reflection of numerous factors.... There is not some overriding criterion of truth according to which works could be measured.... The notion of progress is inapplicable to art because there is no standard goal to which all works aspire, nor could there be. (p. 57)

This can be an important difference to establish in art education where students come to establish the relative values of imagery. Art changes as tools and media evolve and, while there may not be progress as such in art, progress in technology changes art and it can alter the aesthetic and non-aesthetic values of art. Considering the high value society places on scientific progress, it is likely that "high-tech" tools such as computers affect the way individuals interpret and value art. This is the case for the modern fine arts world where novelty and technological innovations are valued. It is too early to see if the sophisticated exemplars of computer graphics made by professional artists will stand the test of time, but the very nature of the flexible imagery and changing methods of viewing and printing suggest they are not likely to stand as seminal works of art in the same way traditional print imagery has. As art, digitized imagery is constantly being replaced by new innovations and remains valuable only as exemplars of technological progress.

Educational concerns must be focused on the way such technology serves artistic ends which are culturally determined. For design tools used by scientists and in the applied arts to demonstrate, illustrate, and depict natural events, there is progress; progress for imagery used for communication or as agent for social change but digitized imagery can also become regression for art that relies on complexity and subtlety of form for its ability to provide aesthetic experiences. Progress in art that is made possible by computer graphics can only be in terms of easier access to diversified forms of art without necessarily reaching any objective realities or finding new truths.

Chapter II: Summary.

1. Digitized imagery is a powerful product controlled by scientific and commercial interests; defined, constructed, and manipulated through the pure numbers and algorithms that constitute the imagery. This type of imagery and its unique image-making techniques present a powerful, ubiquitous influence on all imagery; it reflects the values of the scientific-commercial forces in Western culture.

2. Computer graphics developers are unaware that the effect of their technical innovations is to influence thought patterns and alter the conceptual foundations of individuals and culture.

3. Digitized images are a contrast to more traditional "analog" images where originals are distinguished from copies and access to images is more difficult and less transparent. The result is a view of art that is rigorously defined and quantified on the one hand while, on the other, it is trivialized by the facile way it is altered and shared.

4. The commercial value of digitized images is problematic for the Western art world which historically and economically favors hand made art objects over machine made art, unique art from individuals over anonymous illustrations produced in large numbers, fine arts over the popular or commercial art found in everyday living, and the mysterious force and appeal of paintings that defy complete analysis over mathematically defined digitized images.

5. Critics who suggest computer art is nonsense, dreadful, or ugly junk, fail to show how such art differs from other popular art; they assume popular art is inherently inferior and less educationally worthwhile than fine art. This is a reflection of social critics who argue that popular art is part of an insidious domination associated with the modern technological society. This view fails to acknowledge the empowering effects of educational experiences with computer graphics and the aesthetic value of popular art for the vast majority.

6. The scientific-commercial world assumes that computer graphics represents progress for all image-making. It is an improvement for illustrators, designers, and researchers who perceive digitization as a revolutionary innovation. Thus, digitized imagery is placed primarily within the vernacular arts where it is seen as progress even though there can be no progress in art or aesthetic value *per se*.

Chapter III: An Electronic Paintbrush

> There is more information available at our fingertips during a walk in the woods than in any computer system, yet people find a walk among trees relaxing and computers frustrating. Machines that fit the human environment instead of forcing humans to enter theirs will make using a computer as refreshing as taking a walk in the woods. (Weiser, 1991, p. 104)

Weiser's statement opens with an obvious truth but the added notion that we can adapt machines to a human environment in the same way humans adapt to a natural environment raises a number of questions. For example, to what extent can individuals separate the human environment into distinct components such as *technology* or *art*? How can such concepts and the associated objects be "non-natural" parts of "natural" human environments? Is it more a question of the degree of cognitive response to the environment required under specific circumstances and the type of technological mediation involved? Distinctions are necessary when there is an attempt to discuss the way one area of human cultural practice such as art is related to another such as technology. However, in the educational enterprise, it is important to clarify the implications of such distinctions in order to determine how students' artistic and aesthetic values are influenced by educational experiences.

All humans breathe air, ingest food, and sleep; they are born and die in a shared biological framework. Human activities involved with eating or procreation can be seen as cultural practices but they also take place at a "natural" level that is not mediated to the same extent as the cultural practices that seem to be an inherent part of such activities. The same can be said for the making of objects that hold interest over and above their utilitarian benefits or, for technological developments in general, since both art and technology are present in virtually all cultures in some form. All living creatures mediate the effect of environment as they strive to survive and distinctions between human mediation defined as technological development or art-making are also an integral part of a holistic interpretation of the world; a "natural" part of the world. As Mumford (1952) noted, the human species lagged in terms of technical proficiency compared to other species such as bees, bats, or electric eels until there was a recognition of other unique human capacities. Mumford (1966) adds,

> if technical proficiency alone were sufficient to identify and foster intelligence, man was for long a laggard, compared with many other species. The consequences of this perception should be plain: namely, that there was nothing uniquely human in tool-making until it was modified by linguistic symbols, esthetic designs, and socially transmitted knowledge. (p. 5)

A "refreshing walk in the woods" is presented by Weiser as a stark contrast between the man-made, often machine-mediated, environments and the "natural" environment. However, this image assumes a benign woods that does not hold sinister packs of hunting wolves over the horizon or elusive deer that must be stalked and killed to avoid starvation. During a bitter winter, deep snow and frozen ponds make the woods a dangerous place. If we needed to start a fire for survival during our walk in the woods where there are no matches, flint, or dry sticks, we might find the walk in the woods as frustrating as our computer's operating system. In other words, feeling refreshed or frustrated by the computer is as much a matter of humans fitting the machine's environment, no matter how ubiquitous its presence, as a machine fitting the human environment. Furthermore, the degree of comfort is likely determined to some extent by an individual's knowledge and understandings.

In Weiser's view, computer graphics could become a ubiquitous part of a natural human environment but there is a tacit assumption that the individual's reality would be unchanged by the technology. The notion of such separate, non-natural but essentially neutral "technological" environments is assumed and reflected in most writings about computer graphics. It is explicitly exemplified in the "narrow" view. Individuals are considered a part of a "natural" world and "their" environments can be moderated by technology which is seen as a distinctly "non-natural" force. This is the view of influential writers such as Negroponte (1991), Kay (1991), or Foley, van Dam, Feiner, and Hughes (1990) who emphasize the need to improve user interfaces so computers can recognize human needs and adapt to human concerns and environments as neutral tools. However, an individual's world-view is always constructed in part through both technological and cultural influences. This makes any use of computer graphics, no matter how subtle, an overt influence on an individual's understandings. That is, no machine "fits" a human environment since there is no actual separation of a natural human environment from non-natural, technological areas that exist outside of the cultural practice of society.

Kay, a major influence in the development of the early Macintosh software that set the standard for graphic interfaces is interested in creating two-way communication with computers and ignores or downplays the inherent bias of the technology that will necessarily limit and influence what can be achieved. Kay says, "The icon-based interfaces we developed in the 1970s were oriented toward being able to easily teach people about the system. The new interfaces will be based on teaching the system about what the user needs" (Moad, 1991, p. 64). However, there is no attempt to inform the machine about mental processes of human beings who do not "naturally" cut and paste, zoom in on details, fill specific areas with color, or animate three-dimensional solids that always obey rigid laws of perspective and coherence. The two-way communication systems intended to make the interaction more "user friendly" will still attempt to hide the data structures and the algorithms used by the computer from the average user. In short, the image-making will continue to reflect the same inherent biases of software, hardware, and scientific or technical oriented developers. This means there are likely to be more transparent interfaces in the future and more of a "fit" in the way Kay sees it but as the first chapter showed, the real control and degree of freedom in image-making will be more restricted by the technology as it becomes more ubiquitous. As Marcuse (1966) said, the abiding notion of neutral science leads to a notion of neutral technology but, "In view of the internal instrumentalist character of scientific method, this interpretation appears inadequate" (p. 155).

Computer graphics developers such as Kay make assumptions about how individuals perceive imagery based on a scientific view of reality; theirs is a scientific understanding of a world where science is the body of laws and theories that make sense of the natural world as well as a mode of inquiry into those same laws and theories. Science and its mode of interpreting the world is taken to be an integral part of reality and objects are seen within current scientific explanations. As Borgmann (1984) says, "Our common understanding of the world is always - and already - scientific. More precisely, everyone takes a protoscientific view of the world. The objects around us, large and small, are seen *within the range of scientific explanation*" (p. 19). Technology is considered to be applied science. While there is general acknowledgment of the subtle and complex ways technology will involve knowledge, process, or product such that it manifests itself as a way of thinking, a set of structured activities, or as a specific object, Western views continue to be dominated by a scientific mode of thinking and the assumption that technology is the application of science to everyday living.

There are important differences between traditional image-making techniques and computer graphics technology that affect the way students see the art image. For example, art could always take the individual out of time and place. In Western art, it was usually a matter of showing an exotic inferno or a gilded heaven where the art work relied on faith rather than knowledge to achieve its effect. However, electronic media such as video, photography, or computers, present a new dimension, an added distortion of natural perception that changes basic notions of time and space. A few minutes of film show how a flower unfolds even though the actual event took several hours or how a bullet penetrates an apple, something that took place in a fraction of a second. This takes an individual out of a normal time frame. Similarly, detailed pictures of earth taken from outside the atmosphere and graphic photographs of active organs inside a living human body change notions of how human beings are situated in space. When students are actively involved with the digitization process, they use their knowledge to incorporate new conventions; they decide what perspectives or colors are best or most "natural" and they accept imagery as quantifiable pixels that are quickly and easily manipulated.

Modern technology such as photography has been an influence on the Western world-view for some time but computer graphics is the most recent and most powerful influence. The latest manifestation of such technology is "virtual reality" which is making inroads into the entertainment industry, science, and other areas. *Virtual reality* is a concept that defines various computer-related technologies that are combined to create an artificial environment in which computers and a variety of sensory mechanisms such as wired goggles and gloves create a simulation of an actual visual and tactile experience; a virtual world generated and controlled by computers. For example, Johnson (1992) describes a simulation system used in France by

Renault to test driver's acceptance of real-time data exchange between the car and the outside where information could be fed into the car by road signs and toll booths. It is part of a broader attempt to test the future driving environment where such interactive control is expected to be a part of the average automobile. Johnson writes, "The trick is making this 'cooperative driving' simulation appear so realistic that the test driver's subconscious is fooled into reacting normally" (p. 28). The sophisticated software from Silicon Graphics used to create this simulation cost less than $200,000 instead of the millions required to accomplish such effects a few years earlier and similar technology is now in arcades along with its new conventions.

In the last chapter it was argued that computer graphics presents students with a strong cultural bias for scientific-commercial images with limited form and content. This bias is extant at all levels and dominant in the commercial software used in schools. This influence could be completely unrecognized by the young and it is there even if they don't make any digitized images themselves. Once students are exposed to image-making with computers, overt knowledge of the technology's unique characteristics and the associated techniques will necessarily become part of their world-view. The way they see images becomes an amalgamation of their cultural and technological knowledge which leads to a holistic world-view of imagery that necessarily influences their aesthetic and non-aesthetic values. In the same way individuals come to accept and value the form that is perpetuated by digitized imagery in a cultural context, they come to expect and value the easy way any image can be transposed and manipulated.

Experiencing the Art Image

Most older students who are exposed to computer graphics have already accumulated a great deal of knowledge about art. They distinguish some drawings or paintings as art and they understand photographs as mechanized views of the physical world, regardless of their aesthetic qualities. They also know computer graphics involves a digital "sampling" even though the images resemble paintings, drawings, or photographs. For the uncritical eye, there can be a strong temptation to see computer generated images as the best approximation of the reality registered by human eyes. But, as Wilding (1982) says, "The visual information at the eye consists of a two-dimensional pattern of points of light varying in location, intensity, and wavelength, but our experience is of a three-dimensional world of solid objects, such as trees and squirrels" (p. 17). Individuals rely on immediate sense data from an object to the eyes for the most primary purposes and always interpret raw data as images that are perceived. Thus, experiences with the solid objects of the world that are engaged aesthetically, objects encountered while walking in the woods or placing paint on canvas, are experienced differently from digitized images that are rationally defined "simulations" regardless of how closely they correspond to other images. The process of seeing in itself does not change from one generation to the next but technology changes the sense of reality as the world is perceived through cultural traditions.

Human beings are informed by responses of the nervous system to the physical world and share some common ground through color vision, perception of motion, and so forth. However, shared physical sensations are also interpreted through high level thought processes that allow the construction of a meaningful and coherent view of experiences. This notion of perception as a unity of sense data from responses of the nervous system and complex, high-level cognitive thought processes can be demonstrated in several ways. For example, this registration of an image on the retina or a sound wave on the ear drum is translated by the mind allowing individuals to make sense of photographs, films, telephone calls, and other auditory or visual data that inform them about time and place where they are not actually located. They fragment the information, review it with the necessary skepticism, and place it in their world-view. This is both an individual way of perceiving the natural world and a cultural way of constructing a collective reality through symbolic communications of customs and rituals that inform individual perceptions, feelings, and behavior. Thus, perception of all imagery is primarily an active construction of what is "out there" rather than pure replication in the mind's eye of a fixed image in physical reality and a great deal of what is perceived depends on cultural understandings.

Kepes (1970), an influential thinker about the phenomenon of computer imagery, set the stage for later developments in computer graphics by promoting scientific understandings through a suggestion that artists must, "cultivate those neglected areas of their creative imaginations which can render them responsive to the new scale.... adjust to and communicate with architects, engineers, city planners, and many others who are working at reshaping the environment" (p. 65). However, these are the same scientific-commercial communities that view the inherent bias of computer graphics as an important asset. Kepes (1970) says, "Vision is a fundamental factor in human insight. It is our most important resource for shaping our physical, spatial environment and grasping the new aspect of nature revealed by modern science" (pp. 60-61). The prevalent view in the field of computer graphics is based on scientific understandings of human vision and tends to devalue the fact that what is seen is more a matter of interpretation than an accumulation of raw data by the senses. Developers depend on a tradition where the successful use of physical measurements is the most important means of informing the understanding of what is seen and they use scientific knowledge about human physiology to inform development efforts. For example, human eyes uses constant, unnoticeable and involuntary movements, physiological nystagmus, to scan the field of view. Developers use their scientific understandings of this to design screens that are refreshed by electrical impulses at a rate which allows a "scanning" human eye to see steady images and animated sequences with the greatest economy of resources.[12]

Traditionally, vision was considered the principal cognitive sense and the training of the hand to draw was seen as a means of training the eye to see for both understanding and appreciation. As Gombrich (1982) shows, interpretation of art imagery relies in part on cultural conventions and in Western culture such conventions as formal perspective will inevitably influence an individual's world-view. The world is rarely viewed with monocular vision from a static position directly in front of a static object. Yet we often accept such views as a "true" view of the world or a valid interpretation of reality without a conscious cognitive effort. Similarly, peripheral vision, the blurred area outside the fovial or sharpest area of vision, is always invoked in human vision and there is a time dimension to perception that influences what is seen and interpreted. Such factors are readily accommodated in the learned engagements with imagery and they become an integral part of students' world-view at an early age.

Rudolf Arnheim and Ernst Gombrich present different views of the way art is seen that can inform the understanding of digitized imagery. Gombrich (1982) says individuals isolate and select from an astronomical number of stimuli in everyday living and match what is seen to what is known in order to build theories of art perception and art-making. Gombrich argues that all artists see what they can make as art and their visual concepts are suited to the purpose of their art; they rely on historically important graphic conventions and depict what they know. In Gombrich's view, Giotto and other Renaissance artists developed the convention of formal perspective which provides a common, understood frame of reference that works for Western art. Such conventions allow individuals to perceive art; it thus becomes a shared human phenomenon.

The tacit dependence on such conventions as formal perspective has been a dominant feature of computer graphics since its inception. Formal perspective has been an integral part of Western art since the Renaissance and its continuing influence is seen in recent times through photography and film. Formal or linear perspective is still referred to as Renaissance perspective and it is an inherent part of computer graphics where it provides a model of the scientific methodology that represents Western ideas about visual reality. The ability to easily include simple formal perspective is an attractive and much advertised component of graphics software. Commercial products such as *CorelDRAW*, *MacDraw*, *Aldus FreeHand*, *MacDraft*, or *SuperPaint* can make formal perspective the easiest way to make imagery for the novice and professional alike while they are almost forced to rely on scanned images for other approaches to perspective representations. Pelfrey (1985) says that the computer is the next generation perspective machine and that it, "applies Brunelleschi's formula with the speed of light and can feed back perspective images ranging from the inside of the body to unseeable stars in space" (p. 344). As Pelfrey notes, students are in a position where they can depict their images with perfect perspective at a keystroke in a way that was only possible before with great skill and knowledge. They come to know such manipulation with the unconscious acceptance they apply to snapshots, film, or video. With computer graphics, the rigorous reliance on scientific conventions is extended to the use of colors, shapes, animation, and so forth.

Arnheim (1966) bases his theories of art on an understanding of primary human vision and *Gestalt* psychology. Arnheim assumes a neurological structure that can be shared by all humans; his gestalt psychology of art assumes a human response to visual forms that is biologically determined. That is, the mind organizes all the formal properties of an image into a meaningful whole. In this framework, computer graphics developers define the formal properties of natural objects exclusively through individual dots, shapes, or solid objects in the simplest way acceptable to human eyes. Imagery is presented as a whole on a screen or printer where it is to be organized by the mind into a meaningful image. In short, as Arnheim says,

> Gestalt psychology has made indeed a substantial contribution by showing that the organization of visual patterns is controlled by internal neurological and physical mechanisms, among them the tendency toward the simplest attainable structure. Equally basic to the gestalt approach, however, is the respect for the stimulus, that is, the axiomatic assumption that the images of the sensory world come to us not as amorphous raw material but as structures. (Arnheim's reply in Carrier 1986, p. 254)

Developers rely on the scientific understanding of human vision and a few historical perceptual conventions which are incorporated and accepted as reality. They incorporate basic visual-organizational rules codified by gestalt psychologists in the 1930s and assume a viewer will always organize individual visual stimuli into larger holistic shapes, forms, or limited grouping of elements; an emphasis of a whole over constituent parts according to similarity, proximity, continuity, and closure (Foley, van Dam, Feiner, and Hughes, 1990).

Gombrich (1973) recognizes the way gestalt shifts alter experiences of art. He describes a technique of looking at a painting through a cardboard tube to cut away the frame and other external references in order to make this point and writes,

> Looking at a line drawing we would obviously have to see enough to be able to make sense of the configuration before the effects of illusion could take over.... If we narrow our tube, the moment will surely come when we see the medium rather than the message. There will be senseless lines rather than a representation. (pp. 235-236)

This is always the case for digitized images. The involvement of individual components, a focus on non-representational points or lines rather than a holistic representation, is the rule rather than the exception. Students who work uncritically with the technology can come to see images in a new way since they are constantly shifting their gestalt and they are limited by narrow conventions developed for, and by, scientific-commercial interests; they can come to accept and value the way art can be manipulated and viewed through simplistic formal elements.

Unlike computer graphics developers and the many proponents of the "narrow" view, both Gombrich and Arnheim agree that all art tools, materials, and techniques carry a bias. They both recognize how such bias will inevitably change the art that is made and how an art-makers world-view will be influenced by the conventions and gestalts. Gombrich (1972) notes how illusion of depth conflicted with the decorative unity of pictographs on gold backgrounds and how the realistic nude in Greek art differed from the simple grandeur of form in Egyptian statuary. Gombrich adds, "Speaking more generally, the technical innovations threatened the artist's tasks of creating a rich and satisfying order with his well-tried elements" (p. 80). Similarly, Arnheim (1986) focuses on the mechanical bias that exists in humans or machines and writes,

> Certain formal qualities suit the instrument so well that they flow from it almost spontaneously. Others require special efforts, lead to painfully artificial results, or are not obtainable at all. For example, since the human arm is a pivoted instrument, it takes naturally to curved movements and curved shapes. A straight line movement requires special control, not only in drawing but also in the handling of a violin bow or in a dance gesture. The opposite bias distinguishes, for example, the loom. The weaver has no trouble with straight shapes when they run parallel to the woof, but the loom has its own rules: to produce a diagonal or a curve, it is necessary to coerce the weave's structure. (p. 125)

For Arnheim, an important consideration is the way art-making tools are a part of the environment that shapes the mind's conceptions and he adds, "To invent a new tool is to change that environment" (p. 127). He recognizes the differences between the obvious limitations of traditional artistic tools with confining physical characteristics, which is a limiting factor within some of the formal dimensions that are linked with each tool, and modern technologies that provide a far more comprehensive, "narrowing of expressive freedom within the range of a particular medium" (p. 113). Gombrich (1977) also notes that a tool restricts choices and the, "familiar will always remain the likely starting point for the rendering of the unfamiliar; an existing representation will always exert its spell over the artist even while he strives to record the truth" (p. 72). The implication is that experiences with art-making tools and media such as computer graphics develop restrictive schemata that are definitive of the technology. As Gombrich writes,

> The artist will be attracted by motifs which can be rendered in his idiom. As he scans the landscape, the sights which can be matched successfully with the schemata he has learned to handle will leap forward as centres of attention. The style, like the medium, creates a mental set which makes the artist look for certain aspects in the scene around him that he can render. Painting is an activity, and the artist will therefore tend to see what he paints rather than to paint what he sees. (p. 73)

Gombrich adds that, "Everything points to the conclusion that the phrase 'the language of art' is more than a loose metaphor, that even to describe the visible world in images we need a developed system of schemata" (p. 76). Gombrich (1982) concludes that nature follows art and individuals depict what they know rather than what they see. Students build a world-view based on their knowledge and understanding as well as their stored set of sense experiences. In this way, black and white photographs are accepted in a colored world, shades or colors in a portrait do not imply the face has darker skin on one side or that the skin is really blue in the crinkles around the eyes, and mathematical formulae and pixels do not present a conflict with analog imagery received by the eye through other media. There can be no naive access to art. Image-makers bring traditional values to bear and individuals bring previous understanding of art into evaluations of digitized art. As Jones (1989) writes, "Embedded in computer imagery are cultural and historical conventions which affect both aesthetic/artistic and technical/scientific formations. In addition, these conventions reflect larger models of cultural reality. Both art and technology are affected by these models of reality" (p. 31). In other words, limited gestalts and conventions reinforced by developers can become the *de facto* understanding of students who approach the technology uncritically.

The views of both Arnheim and Gombrich explain important aspects of the way digitized imagery is developed and understood. There are many subtle nuances to the views put forth by Arnheim and Gombrich that are outside the scope of the thesis, including the difference in their arguments about how individuals draw what they know and what they see. Gombrich shows how conventions are used to make meaning of what the eye senses and the characteristics of computer graphics limit these conventions far more than traditional analog media such as paint; the technology restricts the opportunities to stretch existing schema in a unique way. This is demonstrated by the way the technology relies on formal perspective, rules of solid modeling, and other historically grounded conventions. Gombrich's argument that individuals rely on historical conventions such as formal perspective to provide the frame of reference for art-making is reflected in the way this convention, and similar conventions such as those that determine what colors or shadings are used and how they are invoked by image-makers, dominate commercial software. The conventions are determined in part by historical values and also by the need for standardization and cost effective limitations. In short, students who are constantly exposed to digitized imagery in mass media and while working with computers are experiencing a persistent technological influence defined by commercial computer graphics software; they are learning to rely on imbedded conventions as a frame of reference for artistic and aesthetic understandings.

Similarly, Arnheim's understandings of gestalt psychology and the way individuals respond to formal qualities by assembling them into meaningful holistic imagery shows how individual conventions are brought together to form a whole. With computer graphics, limited gestalts in terms of such things as similarity, proximity, continuity, or closure are rigorously reinforced. As students work with computer graphics their gestalts will be constantly broken and restructured as they "zoom" in and out of the digitized image on the screen and then view the final results on printers or other output media where the image is changed again; they are forced to see the medium more than the message. However, when the final image is realized, the "whole" is determined by the limited software conventions and there is often a "sameness" and "uniformity" which is definitive of most computer art. It is this "sameness" where complexity is limited to repetitive iterations of such things as lines, shapes, and colors, which seems so impoverishing when traditional artistic and aesthetic criteria are brought to bear on computer art.

Digitized Art and Aesthetic Experience.

The perfect answer to defining the exceedingly complex concept of *aesthetic experience* has eluded philosophers and I do not attempt to explore the many varied views in this thesis. However, the notion of a unique experience related to digitized imagery must be framed within a view of aesthetic experience in general. In the same way it is possible to distinguish the viewing of computer art from other art, it is possible to distinguish the unique aesthetic experiencing of such art. Students and professionals alike adapt their art-making and values to the imagery that is popular in the culture. In other words, they change their "aesthetics" both because of the need to engage art in a pervasive mass media and through choice because participation in such art is a valuable aspect of enculturation. Thus, they come to value the aesthetics of digitized imagery through the merging of its biased content into distinct form; unique aesthetic experiences linked to digitized imagery and image-making that are made possible because such experiences always involve both cognition and feeling. There is no reason why such experiences should be inferior to other aesthetic experiences or that the satisfaction is less worthwhile.

The term, *aesthetic experience*, does not define instinctive human behavior, urges, or feelings based on biological instincts or genetics. This can be a fine distinction to make because virtually everyone is raised in social contexts that foster an aesthetic engagement of some aspect of the world. The common eye is instinctively attracted to a sudden movement in a still landscape or to sparkling spots of color on dull backgrounds, but humans interpret such phenomena based on prior knowledge and experience. Like other animals, humans rely on instincts but "instinct" implies a subconscious, predictable reaction to stimuli. For humans, such inherited tendencies seldom appear in a clear way and they will always be invoked prior to engaging the world aesthetically. Unlike animals who function primarily through instincts and behavioral patterns particular to a species, human beings constantly create and amend their natural environment based on historically developed, experientially informed concepts, and values. They do so to such an extent that they often lose sight of the shared organic or biological basis of a human species that satisfies simple drives such as hunger or sex along with complex explorations of more existential shared needs such as a desire for companionship or the shared valuing of beauty.

There are many shared capacities and propensities that can be and are developed in humans who experience primary socialization in a Western culture. The ability and propensity to experience the world aesthetically is acquired along with many other shared human traits as part of a complex totality. Human beings gather in groups and, after satisfying basic needs for food and shelter, enjoy the pleasures of the senses and emotions in a manner that is not directed only by instinctive activity or physical drives. They satisfy these complex needs institutionally and socially through cultural activity observed and accepted by individuals who participate as members of a culture. As Osborne (1984) says, "There is no natural or genetically determined talent for aesthetic appreciation but at most a pretty widely distributed capacity which, fortified by interest, can be cultivated and developed" (p. 33). The primary importance of the aesthetic reaction to form in ordinary experience may be debatable but, just as art was one of the earliest cultural conventions that defined human society, so the aesthetic engagement of the world is one of the most important ways that individuals make sense of their world and their place in the scheme of things.

Aesthetic experience with digitized imagery is governed to some extent by the unique qualities of the object of attention that prompt and are part of the experiences. Such experiences are influential because they can be distinguished from other ordinary experience involving sense perception; they provide satisfaction through appreciation for its own sake. Satisfaction is derived from a totality of experience over and above individual parts. During an aesthetic experience, interest is prompted and maintained primarily but not exclusively by the "form" expressed through the total arrangement. Satisfaction is derived from an intuitive knowing and understanding where feeling is an essential part and the individual attends to both form and the meanings attached to form. As Bailin (1988) writes,

> Art has a meaning or significance for people, and at least part of its significance derives from its form. It is able to have meaning and be expressive with reference to those non-discursive, affective aspects of our experience which defy formulation in ordinary language, and this is possible because the form is part of what is expressed. (p. 35)

There is also a cognitive component in the aesthetic experience of art. In order to distinguish an object as art, a concept is needed. There must be some knowledge of what is shown even though form and content are indissoluble; as individuals experience art they are always aware of the work as art to some extent. Individuals may recognize a variety of objects and ideas in the work and they can synthesize all of these things. As Osborne (1986a) says, "There is no intuitive revelation in aesthetic appreciation.... We cannot perceive (in the widest sense of immediate apprehension) what we have not understood" (p. 337). There is always a need to invoke knowledge, understandings, and expectations to some degree. However, the experience of an art image is different from ordinary perception of the visual world. Dewey (1934) and Cassirer (1944), respectively, say it is like ordinary experience but greatly enriched,

> In recognition there is a beginning of an act of perception. But this beginning is not allowed to serve the development of a full perception of the thing recognized. It is arrested at the point where it will serve some *other* purpose, as we recognize a man on the street in order to greet or avoid him, not so as to see him for the sake of seeing what is there. (Dewey, p. 52)

> Our aesthetic perception exhibits a much greater variety and belongs to a much more complex order than our ordinary sense perception. In sense perception we are content with apprehending the common and constant features of the objects of our surroundings. Aesthetic experience is incomparably richer. (Cassirer, p. 185)

Both views suggest aesthetic experience is an enriched synthesis of feeling and cognition but similar to "ordinary" sense perception. These quotations capture the uniqueness of the aesthetic experience of art that defies a definition based purely on conceptual knowledge and understanding. There is an aspect of art that cannot be defined in terms of rules or concepts and the aesthetic experience transcends other experiences as an individual invokes a complex web of imagination, intuition, and prior aesthetic experience in order to make sense of the object that has captured the individual's attention as content become form. If an object is considered as art, there is aesthetic interest involving feeling and aesthetic judgments but pure feeling without reason is a state of ecstasy or trance, not aesthetic experience. Similarly, meaning in art objects or the search for meaning is always significant for aesthetic experiences but never to the point where the "message" is the only stimulus for the viewer. It is the cognitive component of the "cultivated capacity" for aesthetic experience, shaped by complex cultural-technological bias for unique imagery, conventions, and gestalts, that comes to determine some aspects of how individuals experience digitized art. Furthermore, it suggests the aesthetic value is determined by both cognitive and non-cognitive factors while the stature is determined largely through cognitive assessments based on cultural values.

Thus, new technologies such as computer graphics determine the expansion of styles, materials, and techniques. They shape art and they also shape the way individuals engage and appreciate art as part of a historical heritage that includes an awareness of the economics of fine art, the comparatively lower stature of popular art in mass media, and traditional values of craft that are aesthetically pleasing and useful in everyday life. As Bailin (1988) says, "the rules, techniques, and goals of the tradition provide a basis for evaluation, both in terms of the success of the work within the prevailing framework and in terms of the significance of any departure from it" (p. 45). Digitized imagery is trivialized because of the restricted schematic conventions, a dominance of derivative and commonplace imagery, and its place in Western culture as a vernacular art. This suggests it will provide "impoverished" aesthetic experiences if it is approached uncritically by students and the population at large. In other words, digitized art provides aesthetic experience associated with popular and commercial art, imagery with lower artistic value in Western culture than fine art. This means students incorporate the biased form and content of digitized imagery into their "aesthetic" appreciation of imagery; the aesthetics of digitized imagery, the way it is appreciated for its own sake, is affected by qualities that reside in the object, including characteristics unique to computer graphics as a medium and tool. Only an educated, critical engagement can clarify the values of digitized art and place it in students' wider world-view as valuable in its own right.

The Influence of Technology

The dominant Western view holds that contemporary technology is the direct result of science, a dependence of application on theory. The basis of the scientific approach is a notion of unlimited increase in knowledge and expansion measured by quantitative research. In its most simplistic sense, science assumes there is a linear progress of human knowledge from a starting point of ignorance in early human societies to a vague desired goal where humanity becomes entirely knowledgeable about their natural world. Modern science includes the ideas and abstract cultural activities related to an essential understanding of natural phenomena. It is a pursuit of knowledge for its own sake that looks for a reality of the physical universe through well-defined processes; a search for basic truth understood through predominant theories that give a representation of reality and a basis for practical technological applications. As Borgmann (1984) says, "Modern science lets the world appear as actual in a realm of possible worlds. Modern technology reflects a determination to act transformatively on these possibilities" (p. 27). The inclusion of computer graphics in art education means using the technology as a tool and medium. As such, it is a comprehensive new technology that must be defended in the curriculum against those who see modern technology as an insidious and destructive force in human affairs.

The Dominance of Technology.

The thesis does not address the broader criticism of mass media which suggest it is a destructive force for the fine arts because it leads to overexposure of art that cannot be fully appreciated without deeper contemplation than mass media allows. An exploration of this controversial topic leads to extensive discussions that are outside the scope of this thesis. However, earlier thesis arguments could suggest that digitized imagery is quickly coming to dominate traditional analog imagery and the human response to all imagery. The issue has been raised before and a contemporary scientific-commercial notion of continuous, desirable technological progress has been challenged by academics such as Lewis Mumford and Jacques Ellul who provide a framework for the critique of computer graphics technology.

Mumford sees art and technics as antithetical and antagonistic because subjective, organic art deals with inner life and expression, while objective technology represses expression and impoverishes inner life; art is a counterbalance to a technical world. He bases his analysis on the assumption that both art-making (symbol-making) and tool-making are intrinsic aspects of social practice. Technology, as a formative aspect of culture, is modified by dreams, impulses, and motives that stem from practical needs and inner consciousness (Mumford, 1952, 1970). Mumford (1966) says the nineteenth century brought a new technological emphasis to bear on virtually all aspects of human endeavors which is ominously different from anything that has gone before. He concludes that technology is out of control as an integral part of a power-hungry megamachine that destroys human inner life by its attempts to master nature in all its complexity. Modern "technics" is compulsive and tyrannical while art, "has become either increasingly empty of content or downright irrational, in an effort to claim a sanctuary for the spirit free from the oppressive claims of our daily life" (Mumford, 1952, p. 137).

In Ellul's (1967) view technique is much more than tool-making. Technique is the ubiquitous striving for predetermined deliberate results in all human affairs and modern technology operates and evolves beyond the bounds of human control. Modern concern for efficiency, control, and rationalism is not just a limited means of extending or facilitating human skills but assumes its own inner logic which subsequently becomes a dominant force shaping all cultural development. In Ellul's (1990) view, "Science is no longer confined in distant, unknown laboratories. It is present among us.... Children must not only be taught at once to use technical instruments (the computer) but also given a love of scientific research" (p. 182). Ellul suggests, "*First, all technical progress has its price. Second, at each stage it raises more and greater problems than it solves. Third, its harmful effects are inseparable from its beneficial effects. Fourth, it has a great number of unforeseen effects*" (p. 39). Like Mumford, Ellul suggests the roots of technical activity are found in human psychology where the gap is bridged between instinct and technical acts. However, modern technology is no longer the intermediary of humans and environment but an overt reality of a new relationship between the technical phenomenon and society. Ellul writes, "Our modern worship of technique derives from man's ancestral worship of the mysterious and marvelous character of his own handiwork" (p. 24). He claims there is a complete, irreversible break with past technological changes and, "Those who claim to deduce from man's technical situation in past centuries his situation in this one show that they have grasped nothing of the technical phenomenon" (p. 146). For Ellul, technology is exclusively an artificial, non-neutral, autonomous force with complete power of determination over culturally based areas such as art or religion.

Computers necessarily implicate humans in a technical universe and condition them regardless of how they use the technology. Ellul (1990) writes, "In effect, even in such use we ourselves are modified in turn. In this totality of the technical phenomenon, we do not remain intact.... We are closely implicated in this technical universe.

We are conditioned by it" (p. 37). Ellul (1980) sees a relentless influence where, "Man is still perfectly capable of choosing, deciding, altering, directing . . . But always within the technological framework and toward the progression of technology" (p. 42). In this view, technique integrates machines into society by building a model of reality that is orderly and acceptable to the members society. And, the new world changes at an unprecedented pace which forces a reliance on previous technical procedures rather than tradition, "the whole set of complex and fragile bonds that man has patiently fashioned - poetic, magic, mythical, symbolic bonds - vanishes. There is only the technological mediation, which imposes itself and becomes total" (p. 35).

Both Mumford's and Ellul's views are problematic since they assume all technique is causal and never goal-oriented. Furthermore, they fail to account for many valid gains achieved by technological progress. Their arguments for inevitable technological advance which always results from systemic expansion of pre-existing techniques is not true of medicine or other areas such as computer graphics where technological advances result from goals set by society. Computer graphics was not inevitable, it was not a self-generating, self-motivating, preordained event as Ellul suggests of such technology. Instead, the marketplace dictated the nature of development and there is no preordained path for the technology to follow which is bound by the technology alone.

George Grant, a Canadian who holds a tempered version of Ellul's technological dominance theory, says technology is best viewed as social organization; as an integrated aspect of culture and humanity itself. Grant, like Ellul and Mumford, argues that technology has become an all-encompassing world-view where a state capitalistic framework strives to control virtually all human and non-human affairs while the technological dynamo starves both morality and vision. Grant (1969) writes, "Within the last hundred years, it has become increasingly clear that the technological society requires not only the control of non-human nature, but equally the control of human nature" (p. 118). That is, technique as social organization integrates all aspects of culture and technological society transforms all other scientific, political, and artistic activities into the striving for dominance and mastery of the human and non-human environment. Grant writes, "The dynamism of technology has gradually become the dominant purpose in western civilization because the most influential men in that civilization have believed for the last centuries that the mastery of chance was the chief means of improving the race" (p. 113). He concludes that we may recognize the enormous benefits of modern technology but, "we cannot so easily hold the ways it may have deprived us, because technique is ourselves. All descriptions or definitions of technique which place it outside ourselves hide from us what it is" (p. 137).

Within this view, the pervasive influence of computer graphics suggests a mastering of mass media imagery and, consequently, by integrating such a scientific view into a prevalent world-view, mastering the human response to imagery. However, understanding is not simply a matter of coming to know a fixed entity or reality. Rather, the phenomenological world is perceived in complex ways and simple sense data are always interpreted. In short, there are distinct forces in society and culture that can be discussed as such, for example, technology, economics, religion, or art, but there is no clear domination of one area without influence from other areas. Society is shaped in part by the inherent powers of technology but also according to other values and interests of culture that produced the technology. In a constructed reality where technological influence can only be a part of a broad cultural web of influences that include political, religious, economic, and aesthetic concerns, it is difficult to see how computer graphics is primarily a way of dominating imagery and by extension dominating human response to all imagery. In this respect, it is no different from earlier innovative materials and techniques that extended the available art and added to the artist's repertoire. A major problem with the critiques of academics from the arts and humanities such as Grant, Mumford, and Ellul, individuals who present articulate arguments about the negative impact of modern technology, is that they have had little or no experience of technologies such as computer graphics. They fail to recognize that something is lost and gained when computer graphics is used in the art room and that the advantages can justify the cost. However, they do show how uncritical use of technology can evolve in ways that change culture negatively and how there is progress in technological-scientific terms but not necessarily in humanistic-artistic terms.

Artistic value and the way humans interpret art is influenced by a technology such as computer graphics but that does not mean the influence is obvious or that technology is the exclusive mediator of experience. The fact that the Western world is a technological society is not all that helpful for understanding the world or problematic in and of itself. As society evolves, technology is ever-present in the cultural web but a notion that there are no external controls does not stand up in the context of Western cultures. Here, political, religious, economic, and other forces together determine how technologies will evolve just as surely as the culture both adapts to and is molded by technology. Omnipresent, ubiquitous computers may be a controlling influence in market capitalism but there is no reason to expect computer graphics to be a more destructive or determining force than other innovations. For example, steel and concrete building materials were quickly incorporated into modern art by sculptors but traditional carving in wood and sculpting in marble continued unabated. The exquisite carvings in bone and paintings on cave walls are not replaced by new values or new materials since there is no progress in art or art-making as such only more diversity. The primary value of art, regardless of material used or qualifying labels, resides in its ability to engage individuals aesthetically.

Computer graphics technology is not a fatalistic, one-way path to the destruction of visual art. The complex phenomenon of computers is interrelated with and dependent on other aspects of the Western art world because, like all technologies, it is a shaping of the physical world to human purposes; a phenomenon of both nature and culture.

Technology reshapes the natural world for human purposes and, in the process, it creates new realities that human beings adjust to; it provides benefits but it also imposes burdens and constraints. In this way, digitized imagery is an influence that can change reality in terms of how art is perceived but understanding of digitization shows both the advantage of this type of imagery and the omission of other image qualities. Art-making experiences make individuals more sensitive to a medium as they form a physical and sensual link with the image, technique, and technology.

The Influence of Media.

While it can be argued that computer graphics will not necessarily dominate imagery, it is educationally important to recognize how the modern reliance on mass media to distribute preprocessed imagery to the largely passive receivers in Western society influences cultural values. *Media* are the intermediate agents, interfaces between the personal perception of individuals and some type of information; they can make something possible by enhancing a normal possibility. This may be a matter of changing loudness and spanning greater distances or it may be a transformation that allows something to take place that could not otherwise occur. Media are also constituting agents since there is no expression without a medium. Something of substance, such as digitized imagery, must be constructed before other media convey it to an individual's sense experience where it is again processed and incorporated into the individual's reality. All art perception is active and constituting. That is, meaning must be interpreted and even though a digitized image is less ambiguous than analog art that relies on such qualities as vagueness, indeterminacy, or blurring; it must still rely on a beholder for meaning and value.

In art, a *medium* can be defined as any material or technique that is used by an artist to make or define an art image such that it can be communicated to others. As Benthall (1972) writes,

> 'Media' therefore extends over a wide range: from the most primitive techniques of drawing, carving, moulding, inscribing, signaling and encoding, through techniques such as printing, photography, film, radio and television, which are familiar parts of the modern environment, up to the most advanced technologies such as 'real-time' data processing, computer graphics and laser holography. (p. 20)

In this sense digitized imagery is a medium through numbers that make up the image. These numbers are manipulated by art-makers as pixels and the pixels present opportunities and limits just as stone blocks faced by sculptors provide limited options for carving or as copper plates used by graphic artists provide limited potential for etching. With computer graphics, as for any medium, there is a need to explore the limits and potentials for practical educational reasons and for the sheer pleasure and interest of the exploration itself.

There is some recognition of computer graphics as a biased art medium. This recognition can be attributed to Marshall McLuhan's notion that the message is, at least in part, the medium and a related debate about modern communication media that provides the setting for his well known ideas. McLuhan's statement has been interpreted in many ways but there is a general consensus that new media transform communication of aural or visual messages. Some see technological difference as a key to understanding new media while others argue that it is the way media structure and convey content that essentially defines the differences. McLuhan (1964), Innis (1964, 1986), Ihde (1983, 1990), and Loveless (1990) suggest communication technologies must act transformatively on a given situation which utilizes the technology. Each establishes a framework that allows a comparison between media and a determination of how they uniquely act on human affairs. They use different arguments and terminologies in order to identify similarities and differences yet focus on the way society changes as new media displace or contend with established media. Ihde (1983) says it is a matter of gains and losses, specifically, amplification-reduction, such that,

> the advantage is gained at a price. Your presence to me through the telephone is - compared to global perception - a reduced presence and laking {sic} in the perceptual richness of the face-to-face situation.... It is together that this amplification-reduction makes a medium nonneutral or transformative of human experience. It is, moreover, a feature of every use of a technology. (pp. 55-56)

Similarly, Loveless (1990) suggests all media distort messages in significant ways; that societies, bureaucracies, governments, and institutions are reshaped; and that underlying social values change because of the metaphors new media instill. He adds, "it is hard to imagine any future medium that will not somehow be tied to the computer" (p. 204).

Harold Innis, along with Marshall McLuhan and George Grant, is a Canadian of note in the 1950s and 1960s debate about technology, mass media, and communication. His contribution is made through an analysis of early Canadian economic shifts and a comprehensive analysis of early communication. In *Empire & Communications*, Innis paved the way for McLuhan by a historical analysis of media as a reflection of mastering time and space. Innis (1964) writes,

> A medium of communication has an important influence on the dissemination of knowledge over space and over time and it becomes necessary to study its characteristics in order to appraise its influence in its cultural setting. According to its characteristics it may be better suited to the dissemination of knowledge over time than over space, particularly if the medium is heavy and durable and not suited to transportation, or to the dissemination of knowledge over space than over time, particularly if the medium is light and easily transported. The relative emphasis on time or space will imply a bias of significance to the culture in which it is imbedded. (p. 33)

Innis was not faced with the full force of electronic media where both ease of transportation and durability are inherent qualities. It is not clear how such technology fits within his theories which depend on the analysis of media in time and space yet his comprehensive analysis of communication technology is informative because it looks at the broad picture. For example, Innis shows how the print culture that replaced oral culture was not only a byproduct of Gutenberg's press. There were many other factors over a long period of time such as the paper-making industries that evolved to produce increasing amounts of cheap paper. Such analysis can be applied to technologies related to computers where there are constant improvements in communication, printing, processors, data entry, screens, and so forth. For example, the digitized images available to students depend not only on computer graphics development but also on optical disks and graphic cards; other technologies that evolve with computer graphics such as telecommunications or cable services; and social forces in areas such as distance education or telemarketing.

McLuhan's most important contribution in terms of this thesis is his notion of the pervasive and unconscious effect of a medium such as the digitized image on individuals. He argues that communications media have social and psychological effects on the audience; they change the sense of reality, social relations, and the consciousness or way of thinking irrespective of the particular content transmitted. In this way, digitization sends messages in terms of the information-processing skills needed to make them and the way they present a bias towards certain types of images; part of the message resides in the medium itself. Thus, the content is less important than the fact that digitized images, as media, provide messages of mathematically defined, culturally malleable images. In this sense, digitized imagery affects how individuals think about all images; an influence that emerges from knowledge of the technology itself and through exposure to the stereotypical digitized imagery. Computer graphics restricts the information that can be carried in form and content as well as the way individuals must think when they use it. This tends to make digitized imagery acultural. In other areas of communication the need for shared culture often presents immense limitations but once form is restricted to the parameters of the technology, thinking processes are also forced to conform. Thus, culturally distinct content becomes a minor influence compared to shared knowledge and understandings passed on to all active users and viewers. Digitized imagery is shared with little or no need to throw off the limits of cultural barriers; it is developed primarily by economically advantageous industry standards on a world-wide basis that leave few options for cultural differences. As McLuhan writes,

> The spiritual and cultural reservations that the oriental peoples may have toward our technology will avail them not at all. The effects of technology do not occur at the level of opinions or concepts, but alter sense ratios or patterns of perception steadily and without any resistance. (p. 33)

It is also important to see the shortcoming of McLuhan's view and its confusion between carrier and content. Just as musicians know music is not in instruments but in people, so artists know images are human creations before they are anything else. With computers, inherent qualities are important for understanding the impact on culture but the message is also a continuation of traditional media that can be interpreted by educated individuals. Computer graphics technology must be appraised from a culturally dependent viewpoint with an understanding of its holistic functions; as part of the complex relationship between knowledge, communication, information, and media. Image technologies are necessarily two-way communication even though there is often an imbalance in terms of who is a passive recipient and who is an active sender. This is the case for TV and newspapers that send impersonal information to a wide audience.

The flow is generally one way from the few to the many who receive it without critical engagement but educated individuals are empowered and they can approach media from a critical perspective.

The Influence of Tools.

Tools are usually seen as the implements and machines that are used as a means to an end. Tools may be as simple as a hammer used on a nail or as complex as a computer used to make art. Ihde (1990) uses the example of corrective lenses to illustrate how technology mediates the way individuals see and experience the environment by making vision "clearer" than it would be otherwise. He adds, "for every revealing transformation there is a simultaneously concealing transformation of the world, which is given through a technological mediation. Technologies transform experience, however subtly, and that is one root of their non-neutrality" (p. 49). Youngblood (1989b) notes that human vision has been assisted by optical instruments or "machines" for centuries and says, "Dürer's boxes were in this sense 'machines'. They implemented physically what then became formal strategies.... It has come to the point that it is no longer possible to suppress the machine part of it" (p. 28). Technology is more than tools and machines since it includes conceptual frameworks that support physical means of production. It follows that both physical and conceptual components are cultural expressions of the Western world and that both reflect and act upon a larger cultural context in which they are embedded. In other words, computer graphics is part of a world where overt and subtle cultural forces both shape and are, in turn, shaped by technology and no tool is a neutral mediator.

Martin Heidegger (1977a) offers a framework for understanding how computer graphics as an art-making tool, a means to an end, carries an inevitable bias; insight into the way individuals experience an everyday world and how technology influences such experience. His notion of *Dasein* or *unity of being-in-the-world* is an antithesis to the positivistic view of the world where appearance constitutes the structure of reality; a world-view where science records facts and then unifies them into a reality that omits questions of historical development. Heidegger (1982) says,

> The basic constitution of the Dasein is being-in-the-world. This now means more precisely that in its existence the Dasein is occupied *with, about,* being-able-to-be-in-the-world. It has in every instance already projected itself upon that. Thus in the Dasein's existence there is implicit something like an *antecedent understanding of world, significance.* (p. 296)

Heidegger's view is closely associated with phenomenology seen as an examination of the foundations of experience and action; the philosophical style emphasizing understanding of human perceptions and bodily activities. It assumes individuals necessarily experience *something* while experiencing; that experience is referential. This also assumes human experience is always mediated by individual interpretations and intuitive understandings. This is a contrast to a scientific view of the world that is primarily a matter of conscious reflections and logical deductions. In Heidegger's (1982) view, objects simply are, they have a *being-in-themselves*, and, by virtue of their abundance, all objects encroach on people. Here, phenomenology is the method of philosophy understood as ontology (a metaphysical theory about the nature of being or existing) and all ontological propositions must be *a priori*. Heidegger (1977a) writes,

> Phenomenology is the way of access to, and the demonstrative manner of determination of, what is to become the theme of ontology. *Ontology is possible only as phenomenology.* The phenomenological concept of phenomenon, as self-showing, means the Being of things - its meaning, modifications, and derivatives. (pp. 83-84)

Heidegger rejects a classical Cartesian concept of consciousness (I think, therefore I am) and replaces it with a notion of *Dasein*. Human beings are distinguished by consciousness, *being-for-itself*, and by the freedom to form identities. In this view, there is no separation of the conscious mind and the matters of the world. Thus, Heidegger denies any notion of a mind-body dualism that is part of traditional notions of a distinct, primary objective, rational, and physical world of objects that can be contrasted with a subjective, mental world of the mind with all of the attending individual thoughts and feelings; the primacy of experience is an intuitive understanding that operates without reflection. Heidegger sees modern industrial technology as a force that has the potential to reduce human beings to the status of animals who have no insight into the possibilities of disclosing things and forming identities. Conversely, the ability to disclose things in themselves can free individuals from such instrumental ways of perceiving the world and the digitized image and lead to a new mode of ontological perception. As Zimmerman (1990) says, great art is undermined by the overt subjectivism and commercialism associated with modern technology and, "Treating works of art and living things as commodities betrays a basic misunderstanding of what they are. If the work becomes a commodity on the art market, for example, it cannot 'be' what it is" (pp. 234-235).

Heidegger provides insight into the way individuals experience such things as digitized imagery. The phenomenology of digitized imagery is reflected in the way individuals perceive a world full of imagery and the way they act in it as they create imagery. As an image on a CRT screen, digitized imagery changes epistemologically and ontologically but not phenomenologically compared to analog imagery. It changes epistemologically because of its unique existence as numbers and algorithms within limits and validity based on scientific rationalism. That is, the way of knowing its nature, limits, and validity, the very grounds upon which the knowledge is based changes when the image exists as pure numbers that cannot be grasped by the senses. The digitized image is different ontologically in the sense that it becomes a disposable commodity, it is used because of its convenience and economy as a throwaway object and it is, therefore, not a thing in itself in the pre-digitized sense. That is, its essential property, nature, and relations of being as well as its relationship to other universals change as numbers replace pigments. As Heim (1987) says, "The electric element fosters an experience of the world that is increasingly monitored, linked, and driven into productive stress. The ontological disclosure of things as sharply perceived, intimately felt identities will be blurred accordingly" (p. 233). However, digitization is not a phenomenological change for the uninitiated since a digitized image as a phenomenon distinct from its reality remains the same to an unknowing eye. *Art* as a concept does not rely on objective referents; a description of the formal structure of the object of awareness and of awareness itself in abstraction from claims concerning existence remain the same. As a phenomenon distinct from reality, a digitized image on a screen is seen in the same way as any other image as a pattern of light and color that is registered on the eye and then interpreted by the mind.

Heidegger's views are far ranging and exceedingly complex and, within the scope of the thesis, the discussion is limited to his notion that modern technology forces society to adapt stricter organizations for communication and commerce. This, for Heidegger, fosters a world-view that nature can be surveyed and manipulated by a dominant subject. Heidegger says that a world-view,

> is not a matter of theoretical knowledge, either in respect of its origin or in relation to its use. It is not simply retained in memory like a parcel of cognitive property. Rather, it is a matter of a coherent conviction which determines the current affairs of life more or less expressly and directly. A world-view is related in its meaning to the particular contemporary Dasein at any given time. In this relationship to the Dasein the world-view is a guide to it and a source of strength under pressure. Whether the world-view is determined by superstitions and prejudices or is based purely on scientific knowledge and experience or even, as is usually the case, is a mixture of superstition and knowledge, prejudice and sober reason, it all comes to the same thing; nothing essential is changed. (p. 6)

In Heidegger's view, there is no separation of artist and art work since each is the origin of the other and art-making is fundamentally changed by technology since art is an important way of disclosing things in accordance with their own possibilities. Heidegger suggests modern technologies restrict and skew disclosing. For Heidegger, modern technology is more than techniques, devices, and systems that combine to define industrialism. Heidegger writes, "The whole complex of these contrivances is technology. Technology itself is a contrivance" (p. 288). It is a mode of understanding things in a modern world-view; an overt contrast to the anthropological notion of progressive human development of tools that led to the sophisticated technology of today which is,

> incomparably different from all earlier technologies because it is based on modern physics as an exact science. Meanwhile we have come to understand more clearly that the reverse holds true as well: modern physics, as experimental, is dependent upon technical apparatus and upon progress in the building of apparatus. (pp. 295-296)

Heidegger's view of technology is existential; it is more than simple techniques with an independent relationship from the person who uses it. Technology transforms qualitatively the nature of experience such that the use of technology amplifies some aspects of experience and reduces others. All images are perceived through individual interpretation and intuitive understanding that come from constructed conventions bound by both culture and individuality. They are not perceived through logical deduction and conscious reflection about a fixed reality independent of human understanding as a scientific view would suggest. Thus, the digitized image is absorbed into and changes reality in the same way as technologies such as film or photography. Without a separation of the subject and object being perceived, there is a rejection of a purely subjective world-view and this means technology acts on individuals just as they in turn influence technology. This view is educationally significant because it suggests individuals can be made aware of computer graphics' bias or influence and subsequently stretch the limits of all aspects of the technology even though they cannot escape them completely.

Heidegger's *dasein* contradicts the "narrow" view where computer graphics technology is seen as a neutral force in an ongoing construction of students' world-view regardless of how it is viewed as a medium or tool. For digitized imagery, the influence is most clearly seen through the way holistic, spontaneous human actions and thoughts are necessarily scrutinized and then transformed into overtly repetitive, programmable sequences. Digitized imagery offers tremendous opportunities for students' image-making but the more comprehensive perceived structure and a holistic mental approach used with most analog art media is usually not invoked in the same way when the image is constructed on a computer screen. Here it cannot be manipulated in the same way as in a drawing or painting where there is a close relationship between the tool, working image, and final product. This separation of the image-maker and digitized imagery is true at most levels of interaction and the image-maker is forced to obey the inherent rules of the particular computer graphics technology used which limits the form and content far more than traditional media. For example, vector graphics is a powerful way of creating and manipulating "wire-frames" or "solid models" but these images must follow precise mathematical algorithms and adhere to a narrow set of rules that define a scientific reality. Similarly, shapes that are "filled" or "gradated" must be precisely defined before the powerful software commands can be used. Such characteristics of the technology result in imagery that reflects both the inherent limits and strengths of the software. Since digitized images are part of everyday life, it means they are incorporated into the world-view.

Computer Graphics Characteristics

This section summarizes the previous arguments by outlining the important characteristics that result in the cultural and technological influences associated with digitization. It also shows how computer graphics can provide worthwhile opportunities for art-makers who take advantage of a its unique characteristics. The cultural influence of computer graphics discussed in chapter two and the technological influence discussed earlier cannot be totally separated. For example, the increasingly pervasive scientific-commercial images that favor the structured formal qualities associated with scientific realism are a result of complex commercial needs but they are also determined by limitations within the technology. Even though most viewers are unaware of the underlying technology as such, they are influenced by its unique characteristics. Similarly, art-makers are influenced by computer graphics' unique characteristics but they are also shaped by the way digitized images are valued within the broader culture.

Some unique characteristics of digitized imagery are quantifiably different from analog imagery. The most important include the non-unique nature of the image, the facile way it is manipulated, and the way it incorporates analog images into its own format. Such qualities, the ability to clone images, the easy access, and the ability to access analog art in a digitized format are also some of its greatest strengths as an art-making technique. Such characteristics provide students with the worthwhile experiences that justify the inclusion of the technology in the art curriculum. In other words, it is a matter of gains and losses in terms of the art experiences that are offered to students; they gain access to new, valuable experiences but they can also lose respect for and valuing of traditional art experiences that are more holistic and manual skill-dependent if computers become the primary or most important way to make art in the school art room or the wider school and home environment.

Postman (1991) argues that technological change always involves a necessary loss of understanding as individuals are influenced by new technology. For example, he presents the impact of technology as a series of gains and losses where culture will always pay a price for the use of new technology which benefits some and harms others. Postman suggests there is a conflict between old and new imbedded philosophies and that technical change is not additive but ecological.

He maintains that there are always significant cultural costs paid for new innovations and says,

> every technology has a philosophy which is given expression in how the technology makes people use their minds, in what it makes us do with our bodies, in how it codifies the world, in which of our senses it amplifies, in which of our emotional and intellectual tendencies it disregards. (p. 47)

The following computer graphics characteristics can present a bias for unique imagery so strong that students and teachers can easily be swayed at the expense of traditional imagery that does not lend itself easily to the software packages used in the classroom.

1) *Digitized images can be cloned, copied exactly without any distinction between a copy and an original.* Digitized art is always pure numbers that can be copied or altered without a trace. As a medium, the digital carrier is capable of providing cloned images in an instant but it is always imagery that can be easily re-processed without any concern for origin or originality. Early print technologies allowed an increasing number of copies to be produced from original imagery but even the most sophisticated reproductions involved a difference between the original plate, drawing, negative, stone, or painting and the copies. For example, an etching plate or silk screen deteriorates a little with each print even though expert print makers can produce large editions with little obvious change. Earlier mass media had significant differences between originating imagery and what was shown in newspapers or on TV. However, in terms of

digitized imagery where the bits are either on or off, the data are the only real version of the art work. Even though they are sent through the mass media in a variety of ways the numbers remain unchanged and there is no need to consider the "original" image as uniquely valuable or different. There are no deteriorating plates, clogged screens, or brittle negatives.

This is the case for all digitized images and any analog image that is digitized assumes the same characteristics as images that may have originated totally or in part from direct manipulations in the computer's memory. Since clip-art is readily available and scanners allow virtually all images to be digitized, students have access to endless possibilities but, as Nadin (1989) writes, this offers, "more possibilities than we are able or even qualified to use" (p. 46). Such observations lead Kruger (1983) to say that the constant barrage of information and images insulate the capacity to react to these images as art and lead Barzun (1989) to say that the oversupply of art is a dire predicament for the modern world since, "Great works too often seen or performed, too readily available in bits and pieces, become articles of consumption instead of objects of contemplation. They lose force and depth by being too familiar through too frequent or too hurried use" (p. 127). These writers point out a concern about the confusing oversupply and frequent overexposure of art which is so apparent with digitized imagery.

This characteristic amplifies the temporary nature of all digitized imagery which is always readily disposable. It also amplifies the free, anonymous access to imagery that makes it trivial to use and reuse with or without modification. This characteristic reduces the traditional Western values attached to unique, personally expressed imagery and the proprietary value that resided with the "artistic genius" of the art-maker. It is also one of the main strengths of the technology. It reduces the elitism that is enforced by the physical characteristics of such art as painting or sculpture and it amplifies the way imagery can be "seriated" without the penalties incurred by mistakes or casual handling that is common and, at times, inhibiting when working in such analog media. This characteristic can provide unprecedented opportunities for "polishing" a rough sketch or found image through iterative experiments or it can provide uninhibited experimentation from the outset. By using the power of the computer in this way, especially if the overall art-making experience combines digitization and analog techniques, students can recognize both the values and limitations of both types of art-making.

2) *The digitized image can be changed with unprecedented ease and speed in terms of color, structure, scale, light, and so forth.* Digitized imagery is unique through the magnitude of difference between it and other imagery in several important respects such as the increasing ease of copying, adapting, or distributing imagery on a wide scale. No other technology can make images that are both as accessible and adaptable as computer graphics.

Brod (1984) notes how both speed and accuracy are extremely influential and powerful features but adds, "By offering us so much power, speed, and accuracy, they are expanding at a breathless pace our concept of what we can - and should - do" (pp. 6-7). The cost of material aspects of changes are eliminated and the formulation of ideas are informed by the calculative modes of thought required. This characteristic is not unique to computer graphics but no other technique is as easy, quick, or inexpensive for experiments. D'Angelo (1988) also offers an enthusiastic view and says, "The computer in the art room can actually enhance the creative thinking and output of student artists. It can do this, in large measure, due to the speed with which it can respond to the artist's desire to alter images" (p. 42). This may be the case but D'Angelo's advocacy of commercial software assume they are neutral tools. For example D'Angelo says,

> Simply put, *you don't have to know how the computer works nor do you have to have any programming knowledge to use today's new bred of computer!* It's as basic and simple as this: if you can do it on paper, you can do it on a computer .... The computer becomes merely another tool with which the artist may work to further explore and visualize his personal vision. (p. 43)

However, the easy access is always accomplished through limited algorithms that are enforced by the commercial software and by the technology as a whole. This fosters a scientific view of rationality, a view underlying all modern technology, where objective knowledge is rationally manipulated to provide authority for image-making. When painting with a tactile sable brush, students are less inclined to proceed with the rational, sequential, planned changes to the image that are necessary with computer graphics. Instead, they are likely to rely on intuitive and holistic thinking as they make the image. For example, even when I am sketching with a pencil in my notebook in order to capture ideas, I produce more thought-out, refined images than when I sketch with a mouse on a CRT. My sketch on a computer screen is initially crude and overtly simplistic because of the way the mouse and the rest of the hardware/software interacts but then I "zoom in" and refine the image to present a version of the original idea that was envisioned. As Bowers (1988) says, computer graphics can present a view of reality that "privileges experimental innovation over substantive traditions, abstract and theoretical ways of thinking over implicit forms of understanding" (p. 9). The lightning speed and streamlined process that is facilitated by the software demeans the seemingly unproductive time that goes along with thinking about the imagery or simply exploring a better idea that is unlikely to be explored with computer graphics because it involves more effort than manipulation of what is already there.

This characteristic amplifies the extensive use of quick, precise alterations that are facilitated within commercial software limits; it amplifies iterative art-making processes that are defined by the limits of the technology. There are no necessary distinctions between valuable and trivial, unreflective, or unproductive changes facilitated by the software; it is easiest to make alterations that rely on built-in features that are powerful for changes to such things as color, size, and perspective. This characteristic reduces thoughtful commitment and the care of execution that comes about in part because of the penalties for mistakes in traditional media. It reduces the value of a comprehensive, contemplative, and holistic approach to art-making.

However, like the ability to clone iterative versions of an image, this is another of the advantages offered to students and the ability to experiment and change things easily and quickly without penalty can offer uniquely valuable art experiences.

3) *Computer graphics lends itself readily to interactive art-making.* Goodman (1987) and Kranz (1974) maintain that viewer interaction and participation is one of the most important features offered by computer graphics. Both suggest there is a desire by intermedia artists to span the traditional distance between fine art and mass taste by involving spectators in computer mediated art. Such art can provide unique and adaptive experiences for each person who comes to it and the actual interaction can be a significant part of the engagement. However, outside the fine art world students must contend with the expectations of viewers who are most familiar with interactive computer graphics through video games where the aesthetic poverty of figures and images are hidden by rapid, usually violent, animation and interactions. This can come to determine how students proceed if they intend to satisfy specific audiences that include their peers. As Gombrich (1977) says,

> All communication consists in 'making concessions' to the recipient's knowledge. It is dictated by the context and the awareness of possible alternative interpretations that have to be ruled out. The beholder's identification with the artist must find its counterpart in the artist's identification with the beholder.... The social context in which this happens has hardly been investigated. The artist creates his own élite, and the élite its own artists. (p. 196)

This characteristic amplifies powerful features of the technology which are closely linked to needs of the mass media, entertainment industry, and contemporary viewers who expect thrills, novelty, and emotional arousal when they engage art. It also provides access to a modern art world's desire for viewer interaction. At the same time, it reduces attention to contemplative aesthetic engagement where art-making and viewing is primarily a personal, individual experience.

4) *Computer graphics provides a programmatic, process oriented approach to art-making.* Kitson (1991), Hickman (1991), and Roszak (1986) suggest that direct programming experience is a way to understanding computer mediated art and the intrinsic nature of the medium. However, it is not clear that programming reveals the inherent bias of the technology since all procedural programming languages carry the same philosophy of industry and commerce as commercial software. It is an important consideration that has far reaching implications, a subtle influence that is generally ignored by those who uncritically advocate the use of computer graphics.

Digitized image-making processes are segmented and sequential such that programming exists on several levels and image-making is always overtly a process. For example, widely used products such as *Aldus FreeHand* provide an opportunity for incredibly sophisticated image-making but there is a limit to each "tool" in the "palette" and strict rules for the sequential way tools are engaged. It is an explicit, overt programming experience. In addition to this restricted process of image-making with individual programs, artists often use several products to enhance images that are first manipulated with other products because of the large processing and storage requirements. This means that virtually all aspects of the image-making process is segmented and sequential. For example, an image may begin as a scanned photograph. In this process, a scanner with distinct software defines how the image is digitized. It is usually a matter of "cleaning up" scanned images or assembling sections. Then *ImageStudio* is used to simulate various photographic techniques. Next, *FreeHand* is used to change the image by simulating painting or drawing techniques. Finally, *Monet* or *Painter* can be used to simulate a traditional style. As Palyka (1989) says, "for strong content to emerge, the artistic ideas must be executed with the least amount of translation into linear, sequential, tool-operating commands" (p. 61).

Such integrated products are widely used in the film industry, design studios, advertisement, and other scientific-commercial areas. The integrated products are continually shown in the microcomputer related literature as advances in image-making techniques. For example, the October, 1990 *Macworld*, has a review of a new Levco product that uses other packages such as *RenderMan* to do rendering and only facilitates 3-D modeling and animation of imported images. This package uses "implied values" and sets up action such as a ball's trajectory by parabolic functions. Using this software requires some knowledge of mathematics and physics but the developer assumes such knowledge, "is essential to creating animation" (pp. 146-147). In the same issue, the film *RoboCop 2* is used as an example of special film effects made using several software products including *Studio/8*, *Adobe Photoshop*, *MacroMind Director*, and *ElectricImage* (pp. 150-151). Another example of add-on software is *Mannequin Designer*, a program that can, "place moving, fully scalable, realistic 2D and 3D human figures of different genders, body sizes and nationalities into your presentation or design" (*Aldus Magazine*, Vol. 3(6), 1992, p. 9). Similarly, *Aldus Gallery Effects* is advertised as "add-on" software that facilitates, "Fantastic frescoes. Magnificent mosaics. Bold embosses. All available with a quick click of the mouse.... You don't need a huge studio and staff to create monumental art. All you need is Aldus Gallery Effects and a Macintosh" (p. 64).

Programmatic, process-dependent techniques enforce calculative thinking in the sense that commands, programs, and algorithms are always involved in making imagery. Making an image with a paint brush is a personal formulation that confers ownership through the uniqueness of the image. The image and techniques may be trite, but paintings bear the stamp of the image-maker's hand; they are seen as private and personal experiences. That is not to say that these aspects of image-making are absent with all digitized imagery but there is a shift away from contemplative personal expression and craftsmanship towards a focus on the logic associated with finite sets of algorithms or procedures; an inevitable automated manipulation of the many dynamic possibilities inherent with most analog media.[13] All algorithms are focused on a processing agenda that is hidden by computer languages. In other words, students always "program" at some level whenever they use computer graphics. The depth of their technical expertise varies with each product and the line between using the software and programming is often indistinguishable. As Palyka (1989) says, "throughout my entire programming career I have always had to remind myself to stay aware of the purposes for my involvement in it. It's easy to get engrossed in coding general problem-solving tasks and forget to make art" (p. 49) and, "all these capabilities sometimes overwhelm beginning students and all they do is explore capabilities, instead of making art" (p. 5).

This characteristic amplifies the simplistic and derivative imagery often seen in both student and professional work. It emphasizes structured imagery and process oriented, iterative image-making while it reduces the interpretation and making of holistic imagery that relies on intuitive, tacit-heuristic-understandings. It amplifies "art-as-problem-solving" where the art-making experience can easily be dominated by the process at the expense of aesthetics.

5) *Computer graphics fundamentally rests on a mathematical basis that enforces the technological influence.* This characteristic is closely linked with the previous one. Together they demonstrate why there is a widely shared formal quality to most digitized imagery in the mass media. The numbers, algorithms, geometric primitives, and mathematical basis facilitates, almost forces, a clean and symmetric geometric quality on imagery - it is difficult to make images without this effect. Fractal art, for example, relies on simple mathematical formulae and small databases to generate complex images that can be analyzed or rearranged at any level of detail without losing mathematical definition. Repetitious and artificial fractal landscapes

created with this technique may be illustrative and novel but they leave much to be desired as art once their novelty has worn off. As Youngblood (1989a) says,

> Combining the apparent objectivity of the photograph, the interpretive subjectivity of the painting, and the unrestricted motion of hand-drawn animation, three-dimensional computer animation (or "digital scene simulation") may well be the most profound development in the history of symbolic discourse.... the most advanced form of photography now imaginable returns us to the Renaissance concept of perspective as a geometric rather than an optical phenomenon and situates reality once again in the domain of mathematical constructs. (p. 16)

All computer graphics theory relies on mathematics. This extends beyond explicit procedures in commercial software that are pre-programmed to achieve predetermined results. It includes the way the image-maker must approach each task. Digitized imagery is a contrast with traditional media such as paint or ink which are analog media. That is, media such as paint or ink are a continuous scale of measurements like the analog voltage signals used for video, volume control, or dimmer switches while a digitized image is always a sample that is reduced to pixels and, ultimately, to pure numbers. The complexity of some digitized imagery, which can rival that of traditional art media, should not disguise the fact that a bit-map is simply a grid with many numbers representing tiny square picture elements (pixels). Subtle gradations, high resolution, and ranges of color seen through screens and printers are merely a matter of the number and layering of the pixels; all digitized images are numerical "samplings" of a "material" world. The mathematical basis is clear and dominant in such areas as solid modeling which is one of the most important areas for the scientific, commercial, and industrial world. Solid modeling software relies on rigid rules of optics for unambiguous renderings. A mathematical-technological bias is reinforced by cultural expectations of reality and the impetus of developers who wish to pursue what they do best, that is, develop new, powerful technical features for its commercially valued novelty.

This characteristic amplifies the simplistic, precise, geometric imagery structured within the parameters of commercial software. It reduces the wider interpretations and variety of imagery that is usually involved in holistic conceptions of imagery in analog media.

6) *Digitized imagery is predominantly scientific-commercial imagery which results in appreciation for the formal qualities and content associated with this aspect of Western culture.* Computer graphics software development is increasingly driven by, and suited to, techniques such as three-dimensional simulation, computer-aided design, and virtual reality in such areas as science, medicine, and mass media. The quantifiable nature of scientific thinking and the scientific-commercial need for cost-effective means of making and distributing imagery is reflected in the development of computer graphics software where each new sophistication and capacity is considered important. New features are quickly translated into better scientific simulations, more cost effective computer-assisted manufacturing, or startling new film effects that suggest quantifiable change is of paramount important. This approach is influencing the

art community. For example, Chordá (1991) analyzes Velázquez's painting, *Las Meninas*, by creating a model of the setting and writes,

> through computer graphics we can recreate and analyze the three-dimensional space that serves as its model. We can also study the color by modifying it in order to analyze the solutions chosen by Velázquez and the viability of other alternatives. Computer-animation sequences allow us to see whether the static expression of movement in the image of the painting is coherent with its dynamic manifestation. (p. 563)

Chordá adds that it is possible to cross the frontier of the frame, create scenes that motivated the painter, place ourselves inside the object of analysis, and define a different relationship with the image. He assumes, "This synthesis allows us to present our analyses in precise visual language, complementêd by the written word" (p. 567). Imbedded in the notion of parsing and documenting all aspects of art imagery is a scientific valuing of alphanumeric representation over traditional tactile, and kinesthetic qualities that are at the core of an aesthetic evaluation of art.

An example of cultural influence discussed earlier is the formal Renaissance perspective which is imbedded in most software. It represents the visual scientific objective realism that is imbedded in computer graphics with underlying techniques similar to those of camera and video technology; scientific objective realism that rests on the notion that symbolic representation is an objective, one-to-one, value-free correspondence to visual reality. Yet, blind reliance on conventions does not reflect human stereoscopic vision, motion parallax, or peripheral vision. Similarly, there is an ability and a propensity to work in minute detail to get super clarity that places all the image in perfect focus. We could use a magnifying glass or a microscope to show how the pencil line is a jungle of rough graphite on the bumpy paper but this is usually not done in any of the usual artistic experiences with traditional graphic tools. However, pixels that form the digitized image are of immense interest to image-makers who frequently manipulate digitized imagery as pixels even though the eye cannot see an image at that level. All electronic simulacra, digitized cultural imagery that is representational, remove viewers from direct experience with reality and focus attention on commercial and scientific imagery that is meant to fool the senses. Thus, scientific data from deep space are shown as television news, faces change from a square to a human face in commercials and solid cyborgs walk through other solid objects in popular films.

Geometric, crisp imagery that corresponds to precise mathematical models from the scientific-commercial world is seen repeatedly in the art work of both students and professionals who use computers. There is a strong tendency towards such imagery and it presents a superior, idealized definition of reality. As Wright (1989a) says, these art-makers look for an ideal, overwhelming, authoritarian sort of "realism" and, "It is as though the corporate power of the media had joined up with the methodological rigor of the mathematicians and scientists to create some final, definitive and coercive depiction of the visual world" (p. 51). In other words, the novelty, part of the visual delight, comes from the way the image-makers get symmetry and mathematical accuracy through techniques such as ray-tracing or particle modeling. The results are clear and crisp images focused at every level of detail in a way the everyday world seen through human eyes can never be. This is perfectly suited for illustration and scientific modeling where the intent is to depict a synthetic image as an account of reality. Even though such an image is not "lifelike" because it is a simplified model, it is the epitome of a scientific truth that is normally hidden from us. This is sometimes taken to an extreme where faking it can be seen to improve the perceptual and cognitive reality needed by scientists or the entertainment industry.

This characteristic amplifies the scientific view of the world and the making of scientific-commercial imagery. It reduces the values traditionally associated with humanistic, expressive imagery.

7) *The influence of commercial software is often dominant in the digitized imagery students value.* This characteristic is closely related to the sixth characteristic described above. However, there is an educationally significant difference in the way commercial software devalues or hides the potential for new, valuable artistic experiences that computer graphics make possible in theory. Instead of offering innovative techniques, commercial software can offer stereotypical alternatives. Most students' digitized art is made through commercial software packages made for professionals who use it for advertising, design and manufacturing, architecture, entertainment, publishing, scientific research, and other business applications. These commercial packages are the most flexible, efficient means of carrying print and imagery of all types. As such, the technology is quickly integrating

areas such as photography, video, film, and TV where "digitization" versions of traditional techniques are increasingly influential and often replacing original techniques. Also, most commercial software employ their own rigidly simplified versions of media such as pens, pencils, brushes or charcoals. However, the digitizing version of these media is highly restrictive compared to the originals and results in imagery that is quite different from a drawing or painting.

This incorporation of other techniques is not unique to computer graphics. Individuals necessarily incorporate existing art as they make new art and they also change their views of art in light of their experiences. However, a plethora of clip-art, scanned images, and other commercially packaged imagery makes it advantageous to rely on the basic commercial software. For example, *Monet* from Delta Tao Software, Inc., promises that, "artists can very quickly generate impressionistic art from scanned images or rough sketches" (*Macworld*, September, 1991, p. 53). Similarly, *Fractal Design Painter 1.2* simulates traditional techniques. Users can chose from twenty paper and canvas surfaces such as long-grain rice or caviar. These can be scaled to make them smoother or rougher. There are twelve brushes, including oil paint, charcoal, calligraphy pen, crayons, felt pens, Vincent van Gogh, and Seurat (*Macworld*, September, 1992). Each product, while very powerful in its own area, must be complemented by integration with other products in an organized sequence in order to be effective. And, as Peterson (1993) observes, "The better one becomes at running a program, the more he or she accepts and works within its limitations. It's not that there aren't always limitations. The danger is when the limitations become unconscious rather than known" (p. 24). This imagery provides a model for students and professionals alike and establishes new values. As Horkheimer and Adorno (1972) write,

> The assembly-line character of the culture industry, the synthetic, planned method of turning out its products.... is very suited to advertising: the important individual points, by becoming detachable, interchangeable, and even technically alienated from any connected meaning, lend themselves to ends external to the work. (p. 163)

This characteristic amplifies stereotypical qualities of traditional media and reduces the unique possibilities offered by computer graphics as a new medium. It also impinges on the way individuals value traditional techniques and raises the awareness of commercial interpretations and valuing of all imagery.

8) *The technology lends itself to trivialized art imagery if it is approached uncritically.* Within the Western tradition, art done in oil paints as large easel painting has artistic value and the work is considered fine art no matter what its commercial value or its aesthetic appeal at a given time in history. Crafts such as weaving or stained glass are considered to be of a lower level of artistic activity, and folk arts such as traditional quilt-making or wood-carving are at the lowest levels of the prestigious ladder of art. What is common to all of these art forms is the fact that they all depend on a comparison to the fine arts, i.e., large easel painting done in oils and directly modeled sculptures, for their place in the artistic hierarchy. Thus, a

medium is more or less valuable as an art medium based on its ability to make fine art. Similarly, traditional art values rest on a historical record of works that originate from individuals who can only be evaluated by their works while their methods of art-making are largely left as a subject of conjecture and, in the case of great art, considered mysterious. The same facility that provides access to computer graphics users can also serve to trivialize art imagery within the traditional hierarchical art world. Constant exposure to good digitized art imagery causes an image to fade from the viewer's awareness and the impact of novel imagery changes to invisibility with the casual showings that are characteristic of the mass media. For example, the way digitized imagery is made shows the technical aspects of art-making. This makes both the imagery and the artist's efforts accessible. As Benthall (1972) writes, *computer art*, as a term, is provocative, "because the very terms in which we often characterize art - 'humanity', 'warmth', 'spontaneity', 'sincerity', 'originality' and so forth - are laden with implicit prejudice against the values of which the machine is a symbol" (p. 51).

Most digitized imagery in the mass media originate from another medium or other digitized images that are adapted to a new context. Similarly, in schools and homes, clip-art is used extensively and popular products such as *PrintShop*, *SuperPaint*, or *HyperCard* include a data base of scanned images ready to use. Matazzoni (1990) explains that pre-digitized imagery is used extensively in desktop publishing because, "Another money-saving efficiency comes into play for publishers who regularly reuse artwork or photographs" (p.

170). Matazzoni quotes a director of a publications company as saying, "savings kick in on the second or third catalog, because it's a similar format and you're using only 20 percent new photos and copy. You can revise copy, resize images - repackage everything" (Ibid). Clip-art, scanners, and frame grabbers allow all analog images to be incorporated into the digitized format. Photography made the *Mona Lisa* and other art available to educators at the turn of the century for art appreciation. It also allowed Marcel Duchamp to tweak the notion of fine art with a small mustache and photography made this Western icon into a ready tool for commercial artists. However, a digitized *Mona Lisa*, is now available to everyone and more readily adaptable. Buerge (1992) suggests the use of scanned images because, "you can find a virtually unlimited supply of clip art in older printed work.... most of the best line drawings that ever graced a page are found in older books, magazines, newspapers, maps, and a host of other sources" (p. 42).

Barreca's (1991) book, *They Used to Call Me Snow White ... But I Drifted. Women's Strategic Use of Humor*, provides an example of the use of digitized fine art imagery. The book cover demonstrates the point raised above. It is illustrated by three pictures of the *Mona Lisa*. They look like the strips of passport size photographs one gets from coin a operated booth in a mall; two-tone "posterizations" made by one of many software packages that allow a photograph or drawing to be transposed into a few flat areas of colour. The resulting image is still identifiable in its new, stylized form. The top frame of this strip was the original *Mona Lisa* posterized, the second had a few small changes to the mouth making the smile into a big grin, and the third had more changes, including a hand to a mouth which is laughing. This picture has been used in a variety of ways by many types of artists. However, ready access to a digitized *Mona Lisa* for virtually everyone is a shift in value; such easy manipulation makes the image into data and tempers the view of art by a knowledge that it can be used in pragmatic ways.[14]

This characteristic amplifies the commercial value of imagery and pragmatic values of image-making while reducing artistic-aesthetic understandings and values associated with traditional fine art.

Educational Research.

The thesis arguments are not always based on empirical research in schools but emerging research on art educational use of computer graphics offers pertinent insights that substantiate some of the thesis arguments. For example, Freedman (1989) and Freedman and Relan (1990, 1992) analyzed some of the processes that were apparent in their students' computer graphics art-making. Their quantitative and qualitative studies look at changes in art-making resulting from the introduction of computer graphics and their research indicates that this medium has a direct influence on art and students. For example, students are inclined to use more stereotyped, recycled imagery but, at the same time, they tend to take greater risks when they cut and paste images with computer graphics software (Freedman, 1989).

Freedman's research shows how the technological amplifies and reduces art-making experiences as discussed in the last section. The nature of the medium as well as the historical cultural usage will determine the way any art medium is used in schools and it is not a surprise to find that computer graphics reflects its inherent abilities for cutting and pasting, simulating air brush and watercolor techniques, animation, and so forth. Such qualities are influential and Freedman writes, "stereotypic quality was added by use of some graphic functions.... more stereotypical due to the geometric shape functions and more sophisticated because of the subtle qualities of the airbrush function." (p. 293). Freedman concludes,

> Although the computer use reflected common uses of a media in classrooms, the computers were not neutral. The research suggested that technical and conceptual peculiarities of the technology in general, and certain hardware and software in particular, should be considered when developing curriculum. (p. 296)

The recent study by Freedman and Relan (1992) was intended to determine if computers were more conceptually restrictive than other media because of the art-maker's need to focus on the technical or production aspects of art-making at the expense of the more conceptual or ideational aspects of the images being made. The researchers questioned naive notions that students would learn to control computers as they learned to control a pencil or brush so that they would not believe the computer was an undue influence on their imagination. The researchers found students were able to focus more on ideation content as they mastered the technical aspects, yet students always reported that the computer influenced their ideas even after they gained control. Corroborating some of Freedman's earlier studies, students tended to favor the computer's strengths rather than trying to simulate the techniques of other media once they became familiar with the commercial software's features. The students relied on easy-to-use commands that were part of the software. Traditional techniques such as water color, painting, or charcoal drawing were strictly limited to the digitized versions that could be invoked by the single click of the mouse. This was also the case for the computer's unique ability to focus on small areas and refine the lines and surfaces and for its ability to make an image through a series of changes that could be retraced and altered at will. Freedman and Relan use the term, *seriation*, to discuss this feature and report that the "final survey/questionnaire indicated that all of the students considered the interactive, and specifically the seriation, capabilities of the software the most enriching characteristic of making computer graphics" (p. 106). They conclude, "The results of the study indicate that descriptions of computers as either controlling student imagery or as just another art medium are inadequate.... computers also influenced production and ideation in ways that are not common to other media" (p. 108).

The earlier empirical research of Wohlwill and Wills (1988) was also concerned with the direct relationship between computers, art, and students. Their experiments with elementary school children and computer art-making suggest there are motivational factors provided by the use of computers in the art room. Wohlwill and Wills (1987) also studied children's art in order to determine the influence of, "mastery, complexity, imaginativeness, and aesthetic pleasingness" (p. 4). They speculate about the positive motivational power of computers noted earlier, but go on to note an overt tendency of computer literate students who were deeply involved in video games to focus on "problem-solving" and a capability to execute complex computer functions in contrast to an "aesthetically design-oriented" approach focused on aesthetically pleasing design. Wohlwill and Wills conclude,

> Media that provide more control, by breaking up the composing area into discrete elements so the child can manipulate, change at will, and experiment without loss of control would promote the expression of artistic creativity of children at this age, although at the price of a more discontinuous, pointillist type of artwork. (p. 2)

They stress the dominance of the cognitive processes in design and add a, "child's creativity could be stimulated through the use of computer graphics *because* the construction of a program provided the child with cognitive control over the process of creating a graphic design" (p. 11). This is noteworthy but it is also necessary to show how such cognitive control acts as a deterrent at times.[15]

Chapter III: Summary.

1. Western culture interprets art through scientific and technological understandings of human vision, gestalt perception, and historical conventions. This is the case for all artistic and aesthetic experiences because there is always some degree of cognition involved.

2. Computer graphics is a biased tool and medium for image-making; whether seen as a tool, medium, or a way of acting on things in the world, it always presents an influence that changes world-views.

3. Individuals will be influenced in a way that differs from the way they are influenced by traditional media; technological influence combines with cultural influence in ways that are incorporated into an individual's world-view.

4. Individuals invoke some scientific rationality because objective knowledge of the technology is always necessary while imagery is manipulated by overtly cognitive decisions; the technology makes theoretical ways of thinking necessary at all times.

5. An ontological shift takes place as disposable, throwaway objects become society's commodities of choice because of convenience and economy; as images are no longer things in a pre-technological sense but numbers or pixels that are easily manipulated and distributed.

6. Because there are always technical and cultural influences at work as well as cognition and feeling during art experiences, technology is not the sole determinant of how imagery is understood.

Chapter IV: Educational Implications

> Technology is regarded as an expression of culture. It is assumed citizens who are technically and culturally knowledgeable can direct development and implementation of technology in accord with generated cultural goals. Art educators are charged with the responsibility for preparing citizens who are knowledgeable in artistic and aesthetic values. Art educators and their students are also charged with responsibility for understanding the relations of these values to other aspects of culture, including the technological. (Jones 1987, p. 72)

Computer graphics is only one of many subjects that deserves attention and time within art education. However, computer graphics is far more pervasive and intrusive than other modern media. It impinges on all the fine arts and it is of increasing interest to students, teachers, and parents. The quotation at the head of the chapter points out a need to understand the dynamic interplay between culture, technology, and art. This view, and the earlier arguments, suggest it is important for art students to study computer graphics because: (1) it offers a new art-making tool and medium for unique, valuable art experiences, (2) it provides educated insights into the influence of this unique technology, and (3) it can clarify the culturally important relationship between digitized art and other traditional art including fine art and vernacular art. If teachers intend to provide students with comprehensive understandings of computer graphics, it is necessary to recognize that computer art as fine art is a relatively small area of interest to students and society and to acknowledge how the ubiquitous digitized images from the vernacular arts (cultural bias) combine with easy-to-use commercial software (technological bias) to influence students. Also, within the broader schooling concerns, computer graphics technology can help in developing curricula that attend to pragmatic, socially meaningful allocations of funding and time; an approach that lets students make informed choices about their future engagement with the technology in both artistic and pragmatic terms. However, the emphasis of art education, as discussed here, is a comprehensive understanding of art rather than specific art training for extrinsic purposes. This view assumes that an educated approach to computer graphics can lead to unique satisfactions and insights for those students who can respond both critically and appreciatively to digitized art images. As Hickman (1990) writes, "Objects produced by artists do their work at a primitive level when they offer delight. But they work better when they interact with individuals who have prepared themselves to appreciate them" (p. 73).

The "Education" in Art Education

Schooling involves a number of valid, socially mandated agendas and art curricula will have to accommodate them to some extent as other subject areas do. For example, Barrow (1981) maintains that, "Schools should promote education, socialization, health, vocational preparation, and emotional maturity for all because these are the important lessons, the valuable instruction, they can readily provide" (p. 73) or, "Schools, as has been repeatedly stressed, do not only educate.... they should be concerned for the individual's current and future physical welfare, leisure and emotional life and with skills useful for everyday living" (p. 113). There is consistent reference to art education as a means of teaching for non-artistic ends in recent educational documents. For example, *Learning in British Columbia: The primary program* (1990), says involvement in the arts has a positive effect on learning in other areas and that thought processes and language may be developed through the arts. It also states that discussion of art,

> is essential in enabling children to verbalize experiences and make them meaningful.... Through their involvement in the arts, they are learning to express their feelings and are beginning to interpret the feelings expressed by others.... The arts are ideal vehicles for training the senses, enriching the emotional self, and organizing the environment. As well, they allow for clarification of thinking and the communication of thoughts to others. (pp. 48-49)

The *Intermediate Program* (1990) also makes reference to the use of art as intellectual development and states,

> The Fine Arts exist as ways of thinking and knowing. They involve creating, responding, questioning, and communicating all components of intellectual development.... The attributes of Dance, Drama, Music, and Visual Arts, together with the declarative and procedural knowledge that give each subject integrity, are essential to the intellectual development of all students. (p. 75)

Art programs are under review by a society that sees a need to address both the intellectual development of students and pragmatic training requirements of a culture that is threatened by a multitude of economic and social pressures. As Phillipo (1992) writes, "Without widespread, systematic integration of the 'new basic skills' into curricula, the need for knowledge workers will be left unmet and our economic position in the world economy will be uncertain" (pp. 2-3). British Columbia's Ministry of Education shares such concerns. The Royal Commission Report on Education (1988) states that education should cultivate minds, provide intellectual development for its social and economic value, offer moral and civic development, and further individual development by building self-worth. The report suggests that fine art (Music, Theater, Dance, and Visual Arts which includes art in society, aesthetics, history, and art production) and practical arts (employing different technological applications) should be brought into the classroom as two categories of subject matter. It imbues both areas with equal value and suggests *Fine Arts* provide students with alternate ways of thinking and *Practical Arts* provide opportunities to create, design, and construct.

In light of such directives, it becomes important to clarify what ends are intended by using computer related activities in the art room. The thesis is not an argument for or against activities or educational theories pertaining to education, training, or socialization *per se*. Each may be appropriate in its own way but it is essential to identify education as a distinct enterprise; such a distinction can be crucial for art teachers who intend to use computer graphics. The distinction made in the thesis between *educating* and *training* follows Peters (1966) who notes that the mere mastering of know-how or skills, even highly prized skills such as pottery, are insufficient for saying someone is educated. Peters goes on to argue that a person must have a comprehensive body of knowledge and some kind of conceptual scheme, an understanding of the principles that organize the facts to make a body of knowledge more than a mere collection of disjointed facts. Peters suggests a person's outlook will be changed by what is known and then goes on to say educating,

> intimates that other activities such as teaching, training, or instructing satisfy certain criteria; it does not pick out any distinctive activity. It is similar to 'teach' in that it can be used, and is used, predominantly in an achievement sense; but the achievements of a teacher may be morally neutral or pernicious, whereas those of an educator cannot be. (p. 15)

"Education" connotes an intent to provide something of value for students. For example, they are not educated to be computer hackers. If educated persons are criminals they are that way in spite of attempts to educate them. As Richmond (1989) writes of education,

> it certainly implies change for the better, and central in this idea of change for many educators is the idea of developing desirable qualities of mind and feeling. Here I am thinking of capacities involving what it is to know, understand, appreciate, imagine, create, judge, respond affectively, by means of concepts, intuition, norms and procedures, that will withstand public scrutiny vis a vis the various important disciplines of thought. (pp. 18-19)

Barrow and Milburn (1986) add, "Although other conceptions are certainly possible, a widespread view is that education is essentially a matter of breadth of **understanding**. It is thus a cognitive matter" (p. 85). However, the breadth of understanding that is pertinent to art will include educational experiences that are not entirely cognitive. As Broudy (1988) says, "In school, as in life, art calls on a special kind of mental activity to deal with a special kind of object" (p. 171). And, Broudy (1971) adds, "There is a substantial, although perhaps not universal, agreement that the aesthetic experience is not to be identified with the intellectual processes of relating propositions to each other, or to the discovering of hitherto unknown relations among phenomena" (p. 105). It is self-evident that art-making experiences cannot be learned entirely through concepts and theories or experienced purely as a cognitive matter. The aesthetic engagement of art, as Broudy (1988) points out, always, "oscillates between feelingful knowledge and knowledgeful feeling" (p. 175). Finally, the thesis arguments always assume *art education* is an essential component of schooling and that it is an enterprise that is carried out in an accessible framework of self-awareness, open-mindedness, and questioning.

Art training is taken to be the mastering of artistic "know-how" intended to provide job skills even though skill development alone is not necessarily useful for contrasting art training with art education. For example, art training requires transmission of skills, techniques, and traditions while more direct, intuitive, emotional experience may be unnecessary or even counterproductive. However, rote learning or repetitive exercise are appropriate for art education when physical dexterity and manual skills are significant for larger achievements. In the use of computer graphics there is a certain need for skill development and cognitive engagement of the technology that rivals that of any other art technique. Thus, art education incorporates all the activities intended to provide comprehensive understandings of a variety of art forms including the necessary skill development. It includes both conceptual art knowledge and the far more elusive acquisition of direct art experiences involving aesthetic perception of form independent of art's utilitarian or moral ends; comprehensive, intrinsically valuable experiences related to art and art appreciation.

Distinctions between *education* and *socialization* can also be made. I agree with Cremin's (1976) definition of education as a deliberate, systematic, sustained effort to transmit or acquire knowledge, attitudes, values, skills, and sensibilities. Cremin acknowledges an involvement of student behavior, preferences, and tastes as well as cognitive understanding. Cremin views education as, "a process more limited than what the sociologist would call socialization or the anthropologist enculturation, though obviously inclusive of many of the same phenomena" (p. 27). This can be an elusive distinction since art room activities contribute to socialization as students learn about the norms of their culture and such art activities also contribute to the self-development of individuals. Such results may be valuable but they are not the primary intentions of art education.

Peters' notion that the intentions of would-be educators cannot be morally neutral or pernicious and Cremin's notion that education necessarily involves a concern about attitudes, values, sensibilities, and something of value lead to complex issues about what it means to be moral and how we establish the values and sensibilities that will be taught. The most important thing to establish is that such considerations are included no matter how muddled or unclear they may seem at times and values are taught as well as they can be. Art enlightens the world in many ways and serves varied instrumental purposes but artistic rationality as it is defined in this thesis, emphasizes direct worthwhile art experiences, involving intuition and feeling, and a more cognitive understanding of how and why art can do what it does in society. In terms of computer graphics, the intention is to provide understandings of exciting artistic-aesthetic opportunities offered by the technology, insights into its unique influence, and contextual experiences that make it socially relevant.

There is a need to focus on objectives of teaching, on pedagogical content. In short, there is a need to be aware of the type of learning desired in order to keep the focus on art. As Kaplan (1990) writes,

> The educator in creative fields has the function of inducing the proper atmosphere of liberty and craft, imagination and restraint, originality and respect. He or she displays the masterpieces of others, systematizes the requisite skills, and finally evokes the unpredictable resources of his or her students so that they may exercise their own limited perceptions of the world and thus know themselves and the world in greater depth. (p. 29)

Potential Distractions.

It is important to clarify teaching strategies if we wish to avoid some of the non-artistic ends that are suggested in the literature. For example, Davis (1974) states, "The computer represents the ultimate creative tool for the artist-engineer-scientist, the ultimate fusion" (p. 97). Wright (1989b) says computer graphics must fulfill its inherent potential, make a unique contribution, "by showing in a systematic and convincing way the underlying properties of the natural world as well as the subtlety of man's relationship with it" (p. 36). Davis and Wright focus on the computer's easy access to scientific imagery which is an attraction for many yet there is no need to include such understandings in the art room and such an emphasis should not be incorporated without critical analysis. Similarly, it is not necessary to focus primarily on imagery from the mass media just because such imagery is dominant in students' lives. Franke (1987) writes,

> While formerly it was the graphic software of scientists and engineers that was a pace-setter for art, this function is now increasingly being taken over by movies, television and advertising.... The realization that this change could well take place within one generation should have an impact on the training of artists and teachers of art. (p. 336)

However, with an awareness of the implication of the cultural and technological influence, teachers can include or omit such a focus as needed in order to foster understandings and interest in relation to the overall educational ends. For example, computer graphics can be a unique medium of artistic expression; a valuable addition to art-makers' repertoires along with pencils, brushes, paints, and paper; and provide worthwhile insights into the bias of the technology which is dominant in the vernacular arts and influential in the fine arts. If a computer is used, it should be because it is the best way to provide an important aspect of artistic understanding; because it is the best method of facilitating the intended learning or expressing artistic ideas. If other techniques or media provide the same learning there is no reason to use computers. As DiBlasio (1983) writes, "It does little good to have marvelous technological assistance for art instruction if one remains unsure about how these facilitated portions of instruction are to be conceived and conceptually managed within the overall scheme of art instruction" (p. 39).

The role of schools is to provide the education defined by society for a multicultural, complex, yet relatively homogeneous population. However, schools are also expected to provide access to trades and vocations without actually providing specific occupational expertise. This can lead to proposals for the use of computers and computer graphics to foster pragmatic skill development related to the work place or alternatives to studio art programs that focus on cognitive understandings of art and visual literacy. The interest in design and other pragmatic uses of computer graphics is an important influence on art curricula because of the public's interest in work skills. *The Royal Commission Report* (1988) states, "learners we interviewed approached school, generally, with a utilitarian perspective. They looked to schools for the benefits they could gain from them, rather than a desire to pursue learning for its own sake" (p. 19) and, "Senior secondary curriculum retains a small core of constant courses but provides alternatives in course selection specifically to prepare students for their entry into the work force or further education and training" (pp. 27-29). Teachers who are concerned about artistic ends will have to carefully weigh the use of computer graphics as a means of keeping up with technology or teaching for "utilitarian" ends.

The pragmatic demands of Western society will influence the use of computers in schools for design, architecture, commercial art, photography, film, and so forth. One of the strongest influences may be the temptation to use the computer's well-established strengths for commercial design. As Greh (1990) emphasizes,

> We see graphics used where they were never used before. In industry and business, graphics are being used in presentations and reports, and are often created by people with little artistic training. What these developments suggest is that there is a growing need for students to explore the imaging potentials of computers, and become critical evaluators of the resulting images. (p. 11)

However, as Morris (1987) writes, there is a particular kind of knowledge, a way of knowing, involved in designing that is more transactional than aesthetic. It is more a matter of dealing with the outer objective world than an personal inner world and, "Such an approach, in the end, must stress the utilitarian rather than the symbolic, the functional rather than the aesthetic, the objective rather than the personal" (p. 199). Commercial and industrial design are not to be confused with art education. These subjects are valid in their own right and they can stand on their own merits.[16]

For some, computers offer an alternative to the traditional studio programs that focus on art-making and craft. For example, Farley and Neperud (1988) propose that an, "interactive relationship uniting creator, computer-mediated art, and audience will allow education to focus more on feeling and understanding than on concrete art production" (p. 222).[17] Computers can also be seen as an important means of understanding cognitive art experiences. Neperud (1988) says aesthetic experiences are best understood as stimuli or cognitive interactions that parallel, "contemporary views of information processing" (p. 277) and, "one of the fundamental differences between the traditional views of aesthetic perception and current information-processing views of aesthetic experiencing is that perception of the artwork is inseparable from memory and the representation of information in memory" (p. 289). Such statements are problematic if studio art-making is important and cannot be omitted or reduced to a process.

Approaches that favor cognitive understandings of art images at the expense of more intuitive and expressive understandings can take many forms. For example, the concept of *visual literacy* was established when visual communications media such as television and video were used in education during the 1970s. It focused on identifying an ability to *read* (understand) imagery i.e., drawings, paintings, or film, and the ability to *write* (express oneself) within visual media (Curtiss, 1987). While the concept of visual literacy has not gained widespread interest, the basic premise is imbedded in the narrow view. For example, Hubbard (1991), writing about art says, "In order to be adequately educated, all students need to have mastered the tool skills of reading and writing; correspondingly, all students need to have mastered the tool skills of image making and manipulation" (p. 12). Similarly, Loveless (1990) writes,

> if the child of the future is to be literate in the contemporary world, he or she will need to learn and be comfortable with two new language systems: the first is 'data in motion', the language of letter and number via the computer; the second is 'images in motion', the language of photography, film, video and satellite communication systems. (p. 203)

Visual literacy could reduce art education to specific conceptual, material, technical skills, and a concise body of culturally valuable knowledge. However, such a focus on the communication of "stuff" can easily lead to activities that are incidental to art; approaches where artistic-aesthetic qualities are minor concerns. Apple Fellow Alan Kay shows insight into this concern by saying literacy includes tools to access "stuff" made by others (reading), skills to create "stuff" and distribute it to the culture, and a third part that involves an understanding of the styles and modes of thought involved in the communication (Kelleher 1992, p. 30). Kay (1991) is influential in the development and use of computer graphics in schools. As one of the developers of the graphics-oriented Macintosh environment that is the model for most graphics hardware and software, he contributed to the underlying philosophy of the graphic, menu-driven interface technology that provides both power and limitations for image-makers. His work at the Xerox PARC (Palo Alto Research Center) and research in the early 1980s with Atari, led to the Los Angeles Vivarium, an Apple sponsored research project at a free-form public elementary school. Kay says, "I happen to think of the computer more as a medium, as a vehicle, than as a tool or a glorified calculating engine" (Silverstone, 1990, p. 24). However, Kay focuses on cognitive learning like most developers, and says,

> If you want the kids to do symbolic thinking and they are eight years old and primarily visual, you have to find a way of getting them to do the equivalent of symbolic thinking using visual images of some kind or another. That is difficult, because visual images want to be concrete, rather than abstract. It is very similar to the kinds of thought patterns we went through when we were developing the Mac interface. (p. 26)

In some of the educational literature that is not directly related to art, computer graphics is seen as a means of providing generic cognitive understandings. For example, Papert's (1980) influential book, *Mindstorms: Children, Computers, and Powerful Ideas,* presents important ideas that can be related to computer graphics. Papert is concerned about the fundamental idea, "that it is possible to design computers so that learning to communicate with them can be a natural process" and that "learning to communicate with a computer may change the way other learning takes place" (p. 6). For Papert, computer graphics present the potential for teaching "procedural thinking" and training rational faculties in the mental skills a mathematician or scientist would find important. As he puts it, the "book is really about how a culture, a way of thinking, an idea comes to inhabit a young mind" (p. 10). And,

> Children working with an electronic sketchpad are learning a language for talking about shapes and fluxes of shapes, about velocities and rates of change, about processes and procedures. They are learning to speak mathematics, and acquiring a new image of themselves as mathematicians. (p. 13)

Proposals for using computers to teach design, visual literacy, and cognitive art experiences are far-reaching and part of the ongoing debate about art and art education. Furthermore, there are valid and exciting potentials in areas such as art history and art criticism but such use of computers and related technology must not be confused with concepts such as visual literacy. The advent of new technology also offers many more mundane considerations. For example, the use of computer graphics will have to be considered in respect to the way we teach art through art-making experiences in existing studio environments that are often messy and dusty. There may be a need to evaluate current notions of art studio and recognize that facilities with dusty ceramics and hot kilns may not be fully compatible with computers and peripheral equipment such as laser disks, printers, and optical scanners that require a clean and secure environment. Computer graphics offer new experiences and a new environment but there is no need to have art rooms with rows of microcomputers where graphics software and conceptual art knowledge provide the art experiences. What is required in the short term are studios that include workstations with robust computers and adjoining spaces where new technology, including computers, photography, film, and video, can be used safely and productively.

The type of considerations about the use of computers outlined above will have to be incorporated into the many choices facing art education. For one thing, an increasing potential of computer graphics in other subject areas as a means of illustrating and demonstrating events will likely influence the way computer graphics is taught in the art room and the traditional notion of making art for the sheer enjoyment of such activity may be questioned by the proposals for visual literacy and design skills. A full critique of the many varied non-aesthetic proposals for art education are beyond the scope of the thesis but uncritical use of computers can lead to such approaches.

Gains and Losses

The technological influence discussed in chapter three includes a notion of gains and losses. This is true at many levels and it is an important implications for the art curriculum when computers are introduced. As Egan (1991) writes,

> The way we construct our reality is a function of the cultural history into which we are born.... I'm saying education is a process of gains and losses; that you gain a certain kind of understanding but, to some degree, you have to lose certain capacities at the same time.... We adapt ourselves to new ways of thinking as we progress through life and always, of course, we hope that we gain more than we lose. (p. 8)

This notion of gains and losses can be demonstrated through the students' experiences with computer graphics. For example, learning about the way analog images can be digitized with scanners and frame grabbers, allows unprecedented access to imagery. However, there is also a loss of some of the awe for traditional analog imagery that was not so readily incorporated into memos and documents. Photography, lithography, and other mass print techniques allowed wide distribution of commercial and popular imagery but computers, scanners, and libraries of clip-art have brought these images to virtually everyone and they can be manipulated as never before. When students are aware of the fact that no image is immune from the scanner and facile software, it is not possible to see the images as they were before such access was possible; the democratic access and control takes away some of the traditional artistic value. However, educational awareness of such gains and losses can change the way they will be incorporated into students' world-view. For example, art teachers can demonstrate that digitized imagery has its own unique attractions while analog imagery remains valuable in and of itself. In this example, it should be a matter of emphasizing how computers provide access to "analog" fine art that is quantifiably different from a digitized version. Analog art such as paintings or etchings can be distinguished as unique entities made by time-honored techniques that require educated skills and commitment to materials. Such art provides a satisfaction to the art-maker and an appreciation from knowledgeable viewers that is educationally worthwhile. At the same time, it does not detract from the digitized access to analog imagery or the integration of such imagery into the vernacular arts that are such an important part of students lives. When digitized and analog art is used together in art lessons, the strengths of both can be emphasized without the overwhelming influence that results from an uncritical, over-enthusiastic approach to new technology.

New understandings of digitized imagery do not have to alienate individuals and society from the delights of the analog imagery that traditionally provided the most highly valued Western art. Yet, this is often the case with an uncritical approach to the use of computer graphics. For example, Prueitt (1984) relates how an artist has to paint ten thousand flowers one dab at a time while a computer using one flower image or one fractal algorithm can relieve the artist of this routine task and create the same number of flowers in seconds. Prueitt blatantly assumes that this is desirable progress for artists and that the computer-generated image with ten thousand similar flowers is as valuable as the image with varied flowers produced by a painter and that it is possible to make pragmatic trades between the time and effort involved in art-making and resulting qualities, including the aesthetic value. Such ideas present a stark contrast to traditional ways of valuing art-making experiences and art works that are not intended purely for commercial purposes. Prueitt also suggests there are obvious advantages in conventions that are an inherent part of commercial software and writes,

> The ancient Egyptians, in all their wisdom, still did not seem to understand that distant objects should be drawn smaller than nearer ones. The Chinese did beautiful work that gave a feeling of perspective by careful arrangement of natural contours of land and water. But the fishermen on the far side of the lake were drawn just as large as those on the near side. In the 15th century, perspective drawing was reduced to a science by the use of the horizontal line and the vanishing point. Thereafter, many artists produced paintings that we call realistic. Since perspective is now well understood, it is natural that we program computers to draw in perspective. Had it not been for the pioneering work of earlier artists, perhaps all our computer pictures would be isometric like the ancient Egyptian drawings. (pp. 5-6)

The problem with this statement is that Egyptian and Chinese art has value in the indigenous cultures and in Western culture. In the same article Prueitt suggests digitized imagery allows valuable new "photographs" to be made with infinite depth of field and insight into scientific phenomena. The ability to produce such crisp, professional products is seen as advancement because students want to make the same "slick" imagery they see in the mass media. As Prueitt notes, "Most people seem to enjoy pictures that display some form of symmetry, resulting perhaps from the bilateral symmetry of our own bodies" (p. 55). This comment is followed by a computer graphics illustration that provides an example of symmetry and Prueitt notes, "It would be difficult for an artist without a computer to keep track of all the details to make sure that the final result is symmetrical" (p. 65). Symmetry or asymmetry cannot be considered good or bad artistically *per se*. However, most of the commercial "draw/paint" software makes it very attractive and easy to use the symmetry provided by the drawing tools and the "cut/past" options while the pleasing asymmetry found in mass media images is often difficult for students to achieve without a scanner or the use of clip-art. As Gombrich (1972) shows, different societies make art for different purposes. The bias for formal perspective with commercial computer graphics software is neither good or bad as such but the expressed denial of technological bias with its ubiquitous influence or the unqualified presumption that it is the only approach to imagery is inappropriate for an art education that strives for comprehensive knowledge and understanding of art and aesthetics. In other words, computers offer gains in the way they can make infinite copies of flowers and the way they can facilitate formal perspective and symmetry. However, each "gain" entails a potential "loss" for artistic understanding that must be recognized and counteracted.

This can be seen in other ways. For example, Goodman (1987) describes how photography is increasingly being integrated with computer graphics and how such involvement is the result of a desire for more control than the traditional photography techniques offers. This control and manipulative power is desired for both pragmatic and artistic reasons. There are many software products that modify scanned photographs or other digitized images in impressive ways and they change them with a keystroke. For example, *Aldus Gallery Effects, Volume 1: Classic Art* has sixteen filters, including Spatter, Dry Brush, Charcoal, Watercolor, and Craquelure, that allow the user to instantly alter an image based on programmed versions of such styles. As *Aldus Magazine* (1992, Vol. 3(4)) states, it is easy to use, "Just open an image, choose a filter, set and preview the effect in the filter's dialog box, and click 'OK.'.... possibilities for exploration ideas are endless.... Transforming images this way can vastly change the feel of photos you use" (p. 12). This product is easy to use and it can be integrated with software such as *Aldus Photostyler (PC), Adobe Photoshop (Mac), Aldus SuperPaint (Mac), PixelPaint Professional (Mac), Fractal Design Painter (PC/Mac),* and similar programs with "plug-in" filters. Again, significant gains for art-makers and photographers who gain control and versatility but also losses in terms of the integrity and spontaneity associated with photographs that can be so easily manipulated. There is no reason to doubt the intentions or practices of teachers who use the inherent strengths of computer graphics and products such as *Aldus Gallery Effects.* In most cases, there are possibilities for counteracting the "losses" that may be involved. For example, there is no need to limit the use of these software products to the simplistic keystroke alterations of photographs or scanned imagery. The effects that are made possible by the software can easily be integrated into the art-making of students without making it a "paint-by-numbers" exercise.

Once these effects are perceived and used as an integral part of the overall computer graphics technique that will translate ideas into art images, the superficial application of a historical "style" is replaced by a knowing application of a powerful way to alter the art image.

There are clear losses. For example, computers and printers are complex pieces of equipment that involve electronics and mechanics which are only accessible to trained professionals. Even a camera is a less complex piece of equipment for the artist to use, to understand, and to teach others about. With photography, there can be a degree of "hands on" intimacy with the medium while students are working with a negative and there is a direct link between an image seen by the eye and the final image. Also, if there are mechanical problems, they can usually be analyzed by the teacher. This is not the case for computers. The internal components, the hardware, are exceedingly technical and fraught with idiosyncrasies and complexity that can be extremely frustrating for the end user if they are not understood. Computers are unique in the way mistakes, errors, or malfunctions are not easily isolated or resolved by those not specifically trained for this purpose. If something goes wrong, it may be software (involving several layered components that can include a variety of application programs, several system files, communication protocols, and operating systems), microcomputer hardware, the interface to video or CRT, the printer, other periphery equipment such as optical laser disks or plotters that are at fault, or it may simply be a lack of understanding on the part of the user.

However, there are also many clear gains. The computer's unique characteristics, such as the ability to copy and make changes easily, hold the exciting potential proponents write about. The unique way that computer graphics allows art images to be worked out through iterative changes should not be ignored or feared because such power can provide new and important art experiences. Teachers need to show students how such power can be used in historical art-making contexts where it is important to bring insights, knowledge, skill, and individuality to bear on the experience. Computers also offer unprecedented opportunities for students in contemporary fine art that emphasizes light, sound, motion, and interactive viewing. The access to contemporary art can be a clear gain if there is a balance between the new and the old. This can be done as art teachers have demonstrated in the past when photography and video entered the schools. Proponents such as Greh (1990), DiBlasio (1983), Preusser (1973), Curtiss (1987), Hubbard (1991), and Greenfield (1984) note how computers present a new attraction for students who might otherwise avoid school art experiences with traditional techniques involving such things as charcoals or paints where there is an emphasis on artistic skills and an ability to draw or paint.[18] These students not only find an avenue into the art room but they begin to access the wider world of art and art-making where both analog and digital art can provide worthwhile experiences.

Gains and losses take place at all levels. Traditionally the art room has been a place where drawing, painting, printmaking, and sculpting in a variety of media along with crafts, ceramics, textiles, jewelry, photography, stained glass, and many other means of art-making have replaced one another or co-existed. However, each medium necessarily takes time and funding away from others. Furthermore, the gains and losses can be viewed in broader terms than the art experiences themselves. For example, it may present a number of hidden art curriculum messages as suggested by Jones (1987) who believes students could learn that, "a. There are simple, correct answers to problems b. Knowledge is fragmentary and unrelated to daily life c. It is proper that knowledge is both controlled and dispensed by anonymous authority" (p. 65). That is, uncritical uses of the technology can lead to the perception that all computer graphics activity is a matter of following prescribed processes that have little or no reality outside the immediate world of the computer. Zuk (1990) raises similar concerns about the subtle ways visual images from clip-art libraries and professional illustrators are fused with written and verbal ideas to create persuasive commercial messages. Zuk goes on to suggest that there is a tremendous need,

> for educators to assist and guide children in their knowledge, awareness and appreciation of electronic art technologies.... Experiences should include a) knowledge and awareness of historical and cultural electronic media perspectives, b) exploration and interaction involving creation or production, and c) development of critical skills and appreciation involving a dialogue process. (p. 28)

It is difficult to allocate scarce time and resources to adequately experience art-making with traditional techniques and frontier art-making that may be controversial in the eyes of professionals and lay public alike. As both Jones and Zuk note, there are important concerns that require discussion and research. Art teachers faced with computers must choose to ignore them or include them. If they include them, they must decide if computer graphics will be used as a tool, a medium, or both. Hopefully, such choices will be made from a solid base of knowledge about gains, losses, and the pedagogical alternatives that are possible and advisable. Greenfield (1984) says, "the damaging effects the electronic media can have on children are not intrinsic to the media but grow out of the ways the media are used.... television and the newer electronic media.... give children different mental skills from those developed by reading and writing" (p. 2). However, it is also important to recognize how the unique influence, damaging or not, is an intrinsic aspect of the technology because art teachers cannot teach "mental skills" without changing their students' world-view even if this is not a "damaging" effect.

<u>A Shift in Resources and Emphasis</u>.

Without detracting from the exciting possibilities of computers, it is necessary to recognize the limitations of time and materials within the art curriculum. There is a loss of time and resources that could be used for traditional methods of art-making; a loss of the time spent on art that is more intuitive and closer to hand and eye. For example, Greh (1990) suggests approximately eight to ten hours of instruction per student is required for an initial introduction to computer graphics. More importantly, there is a need to consider the gradual insinuation of digitized imagery into the consciousness of students to the point where other concepts are diminished and the computer becomes the primary, if not the only, tool of choice.

Teachers see new and exciting opportunities to bring students up to date in a modern electronic world of multi-media. Some teachers focus on the pragmatic design and desk-top publication possibilities while others use the computer's inherent ability to make changes to let students experiment without fear of destroying earlier versions of their work. Others stress the possibilities for a cognitive approach to art-making and opportunities to get students to use computers as more than mere toys. Most share an unqualified enthusiasm for the technology and they use computer graphics in the classroom as a neutral tool without any acknowledgment or teaching strategies that counteract the negative cultural and technological influence. These views are demonstrated in teacher's magazines such as *School Arts*, a publication that demonstrates school art activity. For example, Falk (1987) uses *Computereyes*, a scanning software, to let students manipulate digitized photographs which are then transferred by carbon paper to linoleum for block printing. The enthusiastic conclusion is that, "I had brought my eighth grade drawing unit into the computer age" (p. 21). O'Connell (1987) also uses computers for drawing because they will provide a foundation for computer literacy and writes, "The basic principles of using a computer to store, repeat, rotate or flip, and then reposition picture elements are introduced and explored in these exercises. The students learn about the flexibility and changeability of working with computers" (p. 37). Kary (1986) focuses on the possibilities for jewelry design and the ability for students to quickly, "create and look at more design choices than they can draw with pencil and paper, allowing more flexibility and encouraging creativity" (p. 31). The proposal for this project stated that the class, "would use the equipment as a *computer assisted design tool,* not as a means to create end products" (p. 33). The consistent unbounded enthusiasm for the technology is shown by Sasowsky (1985) who says, "Computers have, in a real sense, put the image back in the artist's hand. Images can be built - synthesized - according to our imaginations, thoughts and memories. This is an extremely powerful and useful way to create, and computers are uniquely suited to do it" (p. 10). Jeffers (1986) adds some pragmatic educational observations: "High-tech hardware and software should always be used as tools, not toys, in the classroom.... What is it that only electronic machinery can do for the lesson, as opposed to any other teaching tool?" (p. 37), Jeffers answers: "students are freed from any fear of failure.... teachers are freed from fears of student misuse and waste of materials and supplies" (p. 56).

There is nothing in these isolated observations that is inherently detrimental to art education but they illustrate the consistent failure in such writings to account for the bias of the technology and the way it both amplifies and reduces artistic expressions. There is no apparent acknowledgment of why computer graphics is so exciting for art education nor of the way it omits traditional understandings of art-making. Such approaches can be influenced and there are alternatives as Greh (1990) and Truckenbrod (1988) show through examples of how computer graphics and peripherals such as scanners, frame grabbers, and printers can be used to make art in a school classroom. Greh says computer graphics should be taught as a new medium that will appeal to a great many students who would not otherwise be interested in art. Truckenbrod's book is a "text for the first course in a computer graphics curriculum" (p. ix). It also focuses on using computers as a new art-making medium that does not rely on older, traditional techniques, such as drawing or painting. The suggested exercises provide examples that allow students to explore many intrinsic characteristics and capabilities of computer graphics. Truckenbrod adds a cautionary note by noting how people can be fooled by the "flash" of computer graphics although, "the imagery mimics the capability of the computer rather than the insights and sensitivities of the artist" (p. 167).

Unfortunately there is still a tendency to regard the technology as a neutral force in the art room and Greh writes, "The computer is not a form of intelligence in its own right. It's just a piece of equipment that waits until *you* tell it what to do. The computer is only a machine, a tool" (p. 21). This is meant to alleviate potential fears of inexperienced teachers but is shows the underlying notion that the computer can be approached uncritically. Truckenbrod also makes an assumption that media can be neutral and says, "the computer is beyond the media. Artists choose the final form of the work to correspond to the nature and content of the imagery" (Ibid). There are many good ideas for teachers who will incorporate new technology, but it is imperative to recognize that ready access to clip-art and the ability to make comic strips or story illustrations by cutting and pasting is not the same as drawing or painting. It is not as simple as Hubbard (1991) suggests when he says,

> just as part of a word processed paper may be continually and easily edited until the piece fully satisfies a writer, so computer generated images can be manipulated until an artistic problem is fully solved. The frustration of erasing, painting over, or starting again from scratch no longer need interfere with artistic learning.... A stored image can also provide an alternative, serendipitous point of departure in the event that a later direction turns out to be unproductive. (p. 10)

Computers are ideal for making collages, they cut, paste, arrange, and merge found imagery efficiently with "undo" moves, cuts, and pastes during iterative experiments. However, this is not the same as using scissors, glue, and imagery cut from "one-off" magazines or newspapers. With traditional techniques there is a need for hand to eye coordination and attention because mistakes are important if an image can usually only be used once, they may even be an important aspect of the art-making if we value the "risk" factor that focuses attention on the art-making. Computers provide freedom to explore relationships and imagery that may not be available with traditional media but they can also lead to haphazard trial and error techniques without contemplation. Quick changes and iterative copies alleviate drudgery, hazards and cumbersome re-drawing while art-making hand-eye co-ordination requires more time and effort for most students and there is often a naive, unprofessional quality to the end result that students find unsatisfactory. With computers, students can take risks and save iterative stages as required for evaluation of both imagery and process. This facility is widely recognized and valued by proponents of computer graphics and it is one of the overt aims of developers to enhance this feature. Sontag (1987) says a computer, "simply provides another potential vehicle for artistic expression.... Its greatest instructional value probably rests in its ability to allow a student to quickly review a wide range of visual options" (p. 161). Once students begin to think about what type of art they want to produce, making haphazard changes that can be undone with a key stroke is not the same as thinking about a painting while placing paint. This ability, taken uncritically or in isolation, does not justify the use of computer graphics. As Bowers (1988) says,

> being able to manipulate information, even with the speed and accuracy of a computer, is not the same as thinking. This is the vitally important point that is missed by educators who urge the adoption of the new technology on the grounds that we are moving into the Information Age. (p. 59)

There is seldom any mention of how time consuming and difficult it is to create original imagery with any degree of complexity or sophistication. And, in order for students to take full advantage of the software it is highly desirable to begin with existing digitized imagery. Bloomer (1990) say that all images, "can be converted into electronic form by means of a video device or optical scanner and fed into a computer. You can then manipulate and reconstruct these digitized images in various ways so as to make them more attractive and easier to perceive" (p. 201). However, technology determines what images are effectively scanned, how they can be incorporated, and, to some extent, how they can be made attractive. Scanning provides a multitude of familiar images that are altered to suit the occasion. For example, a brightly colored digitization of Vincent Van Gogh's self portrait by Jim Jackson won a CA-ImageNation Contest and it is presented as "Vincent Van Cricket" to advertise *CA-Cricket Draw III*. It is now used to sell the commercial drawing package and readers are told to "Gogh Crazy." (*Macworld,* August, 1992, pp. 16-17). In the same issue *Fractal Design Painter 1.2* uses a digitized Van Gogh painting of cypress trees to illustrate its features (p. 154).

For students, computer graphics experience is usually a matter of using commercial software such as *Dazzle Draw, SuperPaint, Aldus FreeHand, MacDraft,* and so forth. With such software, students have to accept the limited scope of each package. Such products are like automated cameras, aimed and triggered while predetermined parameters for exposure and flash are controlled by the hardware. And as Palyka (1989) writes, "The tools of computer graphics have had many years of scientific development by the time the artist enters the picture. When the artist gets the tools, they are already imbued with the attitude of the programmer toward the art process" (p. 44). For example, features that allow cutting and pasting are useful but they act as delimiters to the point where it is difficult to see if students control the medium, or the medium controls students. The problem for teachers will be to use such features so students can manipulate imagery without unnecessary frustration from erasing and, without, at the same time, losing the opportunities to make meaningful, thought out changes that are not easy with the software.

As Roland (1990) notes, most teachers use paint programs and clip-art libraries to participate in, so called, elitist art and,

> The most frequent practice in art classrooms is to have students work on microcomputers with graphic peripherals and "user-friendly" application programs that enable them to simulate drawing and painting on the computer screen.... digital paint programs make computers easy machines to operate. Neither the teacher nor the student needs to know very much about computers in order to work with them. (pp. 54-55)

Like Greh, Roland recognizes the limitations of a focus on "how to" and notes how indiscriminate use fosters the view that computer graphics is: limited to imitating standard fine art technique, only capable of simple two-dimensional art that does not measure up as fine art, and capable of turning anyone into an artist. Roland says, "imagination and judgment must be exercised in determining what choices are to be made with the computer. Otherwise, students may spend their time in incessant experimentation and in turning out endless variations on a theme" (p. 55).

The best solution for teachers who want to maintain some of the valuable art experiences and art values that have stood the test of time would include a use of the computer's unique attributes both as a new tool or medium and as an integral part of the artistic heritage. Walters, Hodges, and Simmons (1988) note how a microcomputer, "can control brightness to an extremely fine degree, and it offers a palette of millions of colors; even so, the computer does not provide a means for applying these elements in a manner that resembles oil painting or water coloring" (p. 108). Instead, they suggest that,

> Today's computers ought not substitute or replace the traditional media.... the computer can be mobilized as an interim step in the compositional process, a place where the artist or composer experiments freely with ideas, changing them, discarding them. The speed with which the artist can alter the composition and the cleanness of the edited result make an ideal forum for this experimentation. In this case the computer becomes a sketchpad; and just as the sketchpad bears a resemblance to the final product but is not mistaken for it, so the computer provides a flexible and efficient medium for experimenting with work in progress. (pp. 108-109)

The Alternatives

This notion of making preliminary experiments need not be the only approach but computer graphics can be used to work out ideas that are pursued in other media. Such alternative ways of using the technology offer the possibility of showing its bias, using it as a tool and medium, and uniting this new knowledge and understanding with other techniques. The scope of the thesis does not lend itself to examples of specific lessons that are derived from the knowledge of the way computer graphics will reduce and amplify art experiences. However, directed experiences with the technology as a new, unique medium can show its value as both a fine and vernacular art and the integration of computers with traditional media as a "sketching" or "finishing" tool can show its link with traditional art-making. In this way, computer graphics can be experienced by students as another addition to Western art with aesthetic value, social pertinence, and infinite scope for uniqueness and self-expression.

The notion of enhancing gains and counteracting losses is not just a matter of allocating time and resources, it is primarily a matter of providing experiences that alter a student's world-view in a way that can be justified educationally. This will be the case in the art room since the technological bias transforms qualitatively the nature of art-making experiences.

There are educationally worthwhile alternatives to the uncritical, enthusiastic "narrow" view and the non-artistic, non-aesthetic uses of computer graphics. Similarly, there are ways to counteract the losses that appear with the new technology and many exciting possibilities when it is used with a recognition of both the possibilities and the limitations. For example, Truckenbrod (1988) and Greh (1990, 1992) show how scanners can distort portraits in interesting ways such that computer graphics is a uniquely valuable medium in its own right. With a similar emphasis, Pope (1988) says, "the computer is the most appropriate instrument with which to facilitate the realization of substantial concerns with kinetic, participatory, and cybernetic art forms, which when mature cannot have other than a major impact on art theory and aesthetics" (p. 323). However, teachers must be conscious of how students have to find or make appropriate images as they would for other projects. In other words, the startling ease of scanning and altering images does not replace the difficult task of making images that have aesthetic value. The images that are useful for this type of art-making are those that fall within the parameters of scanning software but this does not always make them valuable art. Just as only some images lend themselves to "morphing" or other features, only some images lend themselves to scanning.

Ettinger and Roland (1986) also show how computer graphics can function as a unique medium. They show how computers can be used to stimulate traditional studio art activities; control equipment to produce novel art objects; facilitate interactive art, new pattern generation, and real-time animation; and integrate images, sound, and other sense experience in multi-media environments. Similarly, Freedman (1989) uses computer graphics to experiment with art forms that draw inspiration from earlier frontier art and notes how students can then focus on movement, light, chance or randomness, audience interaction, or seriation. These ways of using computers are no more problematic for artists or teachers than other technologies such as photography, video, or holography. In this respect, the art objects function in a traditional way; they are critiqued, valued, and marketed as fine art. Thus, the technology can provide a powerful tool-medium that facilitates experimentation, incorporates existing images, and enhances communication. As Dufrenne (1980) writes,

> What are the implications of the acceptance and use of modern technique? First of all, the desire to befit the times: not yielding to the nostalgia of the past, not choosing flight or exile, but encouraging the development of an art which liberates itself by acknowledging the gains of modernity and using them to invent rather than repeat. For a new world, new art. (p. 168)

In simple terms, the thesis suggests teachers take advantage of the gains and counteract the losses. As noted earlier, the technology can and should contribute to new, unique experiences. Furthermore, it can be used effectively to either prepare or explore ideas that will be extended and integrated with subsequent art-making techniques such as drawing or painting. Similarly, drawing or photography can create ideas that are digitized so further work can take advantage of the technology's superior features for copying, editing, and realizing ideas within crisp boundaries of color or through sharp lines.

Gombrich (1978) writes, "The artist, clearly, can render only what his tool and his medium are capable of rendering. His technique restricts his freedom of choice. The features and relationships the pencil picks out will differ from those the brush can indicate" (p. 56). In other words, each new medium makes its own contribution by defining form through material and it makes unique demands on artistic skills. This is also the case for computer graphics where there are many new opportunities. For example, knowledgeable students can use stored imagery and the computer's ability to copy, cut, and paste without becoming slaves to slick, commercial clip-art libraries and scanners. Such experiences can be balanced with experiences that use contemplation and skills through the execution of a pencil, paint brush, or chisel with direct, irreversible consequence. There is no attempt to justify the value of traditional art-making experience in the thesis but it is far more difficult to make a satisfying drawing or painting than photocopying a van Gogh image and mapping color schemes or textures on a bit-mapped image. The differences between clip-art and personally evoked imagery as well as the differences between computer graphics and traditional techniques can be shown in a way that makes a contribution to the students' education. As Simpson (1985) says, "unless the aesthetic is central to the arts in education then, inevitably, their chief function will be to serve as vehicle for other ends" (p. 278).

Similarly, the computer's capacity for making art where viewer interaction and animation is featured presents many wondrous, new opportunities for students. Franke (1987) writes, "the significance of computer graphics lies only in animation. While conventionally produced images can hardly be put into motion, the computer lends itself almost naturally to this possibility" (p. 336). Goldberg (1986) also emphasizes the value of interaction. He suggests it is intelligent entertainment compared to the interaction students learn with video games. Greenfield (1984) adds, "children take a more active approach to the medium, becoming aware not only of content but of how television's forms and techniques create that content. In short, they become aware of the message of their medium" (pp. 161-162). It is doubtful that animation is the only significance but digitized imagery is based on finite parameters such that controlled change result in exciting motion or animation. It is a useful and tempting feature of many commercial software packages and it can provide exciting art experiences. Like other characteristics of computer graphics, the facile ability for animation and viewer interaction can provide unique and valuable experiences that may be taught in isolation or incorporated into lessons involving other traditional techniques.

An important consideration is the way the digitized image is far more remote from the student than the touch of a brush on canvas. What is shown on the computer screen can be drastically different from the final image quality on a printer and there is a also loss of contact between the computer art-maker and the image at the working level. The manipulation of color, structure, scale, light, and so forth is easy and precise but always part of iterative art-making processes defined by commercial software in a way that is unlike other techniques. Also, computers restrict the artist's view of the image since imagery is usually displayed in parts while detailed work is done. When students use a computer screen, they focus their eyes on the screen while their hands manipulate the mouse or other input device. However, the movement of an input device does not necessarily correlate to the CRT in the same immediate way a pencil moves with a hand; eye-hand feedback is always mediated by the computer and moving a complex image can be delayed by several minutes if the processing is intensive. Similarly, the lines, shadings, or colors on the screen, as well as the size of the image, change considerably on output devices where the result of the digitization process is realized for most student work; screens are usually not the same size as the paper and color or surface qualities can be quite different. Goldberg (1986) says, "I see the place of computer artists in their medium, at the terminal, where imagery is put out in its immediacy - not in secondary output through the printer or photography" (p. 126). This view fails to acknowledge a need for students to make prints as the only way to share and preserve their work outside the studio environment. In such cases there is a transformation that takes place when an image is taken from a screen and placed on paper or canvas. Similarly, new screens are available to display the same image with each technological change. In other words, advantages are only accessible within the limits of computer graphics. Such characteristics can lead students to unknowingly approach art-making in an overtly cognitive manner and to assume printed copies are disposable and trivial. The way the image is manipulated remotely and likely printed cannot be easily mediated by teachers within the art-making experience itself but, such "losses" can be mediated by traditional art-making experiences with more tractable materials. In other words, the integration of the computer graphics into the rich diversified traditional art-making experiences of the art room will prevent students from assuming that computer graphics is the "only" or "best" way to make art. If the use of computer graphics is seen as a way of involving student in the wider world of art, it can help them overcome the trivializing aspect of making and distributing art electronically.

As noted, many students are drawn to the computer and its design-like characteristics. Computers allow students to draw perfect squares, circles, and straight lines with ease. This is attractive for those who have little success with traditional rendering and other activities. Some students now find success through activities related to desktop publication and video production. As Greh (1990) writes, "Many art teachers have noted that students using computers seem to gain an appreciation for abstract design because, in trying to create more traditional images, they find themselves creating non-traditional images" (p. 44) and, "In general, one might conclude that although the content of students' work is not significantly different, students do seem to develop a sensitivity and appreciation for nonrepresentational design, particularly geometric design" (p. 90). Again, if there is attention to the way technological characteristics influence some aspects of the experience, this can provide useful art lessons. As Arnheim (1986) says,

> Computers, as we know them today, produce only combinations of fixed elements. They receive information in the form of bits, and they dictate only patterns whose shapes and spatial relations are reducible to the formulae by which they were constructed. Therefore the technique of computer graphics is particularly suited to geometrical ornament. It is a god sent for weavers and for the designers of fabrics and wallpapers because not only does it execute tediously repetitious work with supreme accuracy and speed, it also can deliver all possible variations of a given set of elements and thereby supply the designer with an inexhaustible choice of themes. (pp. 128-129)

<u>The Art Teacher.</u>

An important concern alluded to but not fully explored in the thesis relates to the implications for educating art teachers who will use computer graphics. For example, there is an increasing emphasis on art programs with structure and instruction; a perceived need for accountability and evaluation. Discipline-Based Art Education is a result of this emphasis. It has changed art education in many parts of North America and shows how art education can shift dramatically in a short time. DBAE represents an approach to art that lends itself to the use of computer technology, and computer-assisted instruction (CAI) software is reminiscent of the "teacher-proof" packages that formed the basis of most programs that were the precursors to DBAE. Computer technology could be a means of providing ready access to text and images related to the four disciplines within the DBAE curriculum advocated by the Getty Trust since it relies heavily on a body of sequential, structured knowledge. This type of educational approach to teaching art lends itself to learning software packages used with microcomputers and video disks that contain a wealth of written information and high quality art imagery. For example, an increasing emphasis on art history and art criticism could be facilitated by microcomputers, video disk, and other electronic equipment. As Anderson (1985) suggests, if the use of computerized discipline-based art education software packages were the basis of teaching art teachers, it would incorporate both the new technology and the new approach to art education.

The overt impact of computer graphics is part of students' lives as video games, film effects, and in many other ways, but in the art room it will be felt first and foremost by teachers. The technology presents both opportunities and problems for teachers and their training will be of crucial importance. Spratt (1987) says that, in art production, "we find avenues leading to a fuller understanding of all art - access to which may be foreclosed when learning is exclusively through the study of the works of others" (p. 198). This observation is no less true for the teacher than for students - to *fully* understand the art of other artists and of students some direct experience of art-making is necessary, not only to keep current with technique and skill, but to act as a role model. For some teachers, computers will present a formidable challenge. As Westwood (1967a) writes,

> In modern society with the emergence of a powerful and pervasive youth or adolescent sub-culture with all its implications, and a growing 'gap' between generations, the teacher's role becomes ever more ambivalent, the task of mediating between two sub-cultures (especially in the 'poorer' schools) increasingly one of strain. (p. 133)

Westwood wrote those words more than twenty years ago. Since that time, teachers have been dealing with an increasingly complex variety of students with diverse social values, intellectual abilities, and cultural backgrounds. This "gap" is amplified by new technology which is more likely to be familiar ground for students than teachers. It is also amplified by economic disparity that give some students access to microcomputers and sophisticated software while others are novices to computer graphics outside their local video arcade.

Teachers need to be familiar with computer graphics. *A Legacy for Learners* (1988), says, "Teachers without academic or professional preparation in new curricula or instructional practices are unlikely to have the commitment or capacity to implement the intended changes effectively" (p. 91). Teachers must know computers well enough to demonstrate software features, as overt socializing agents they must know about the social implications of using the technology, and as art educators they must understand technology enough to recognize both bias and promise. Teacher training is an important area outside the scope of the thesis but one that must be considered in order to avoid a "narrow" view. As Branscum (1992) says,

> Teachers cannot be expected to make up this stuff as they go along. If teachers do not receive appropriate training, computers will continue to be used as electronic baby-sitters.... Such training, in turn, needs to be based on strong, comprehensive research on the best techniques for using computers effectively. (p. 83)

Chapter IV: Summary.

1. Computer graphics is a valuable addition to art curricula where worthwhile knowledge and aesthetic understandings of the arts is important. It provides worthwhile art-making experiences in its own right and demonstrates the influence of technology in broad terms.

2. Computer graphics can enhance students' ability to "sketch" out ideas through easy experimentation-iteration, allow them to "refine" and "polish" finalized art works with the qualities they value in the vernacular arts, provide access to art for those who do not want to work in traditional media, and provide them with opportunities for contemporary art-making experiences.

3. Teachers must recognize how an uncritical approach to computer graphics can lead to its use in such areas as design, visual literacy, and programs with overt cognitive emphasis. They must understand how the technology changes art-making through the way its unique characteristics amplify and reduce some aspects of the experience.

Concluding Remarks

> The most haunting questions concern the impact of the technology on the artist, the creative process, and the nature of art. More specifically, it is asked, to what extent do the available systems and software determine the results? Is an artist creatively restrained by the options available to him, either by available data or by the way in which it may be retrieved? Are new aesthetic criteria required to evaluate computer-aided art? Is the value of some computer art decreased by its non-unique nature and the fact that it may have been executed by a machine instead of by hand? Are all works displayable in hard copy merely multiples? (Leed, 1980, p. 16)

Leed's statements demonstrate the concerns that led to the thesis. There are other questions that do not lead to definitive answers but suggest a need for further research projects. For example, which of the characteristics discussed in chapter three should be emphasized in art education? Should it be a close, intimate art-making experience such as a pencil or pen provides because of the intense interaction of the small screen and artist? Does the enforced iterative process mean ideas should be continually or completely developed without moving to another technique? Is the difference between screen images and other means of recording images such that there are two different concepts from each image?

The thesis is a conceptual study that relies on the professional literature, journals, and other academic writings from such fields as computer technology and art where there is little common ground. This is due, in part, to the ubiquitous nature of the imagery which allows it to be used in art, journalism, engineering, communication, or other areas. Thus, the writing on the subject is an uneven mix of opinion from many interdisciplinary magazines and journals. The variety of interests is reflected in art education where enthusiasts fail to acknowledge the cultural-technological bias and most of those who argue against the use of such technology fail to explain why it is inappropriate. In some instances there is a heady tendency to follow changing intellectual fashion and editors not always familiar with computer graphics are swayed by style at the expense of substance. Art teachers may learn about new technology through such popular magazines as *Time*, *MacLeans*, and *National Geographic Magazine*. For example, White (1970) initiates *National Geographic* readers by saying that computers, "are indeed awful, in just about every sense the dictionaries assign to that word: inspiring dread, appalling, objectionable; solemnly impressive; commanding reverential fear or profound respect; sublimely majestic" (p. 593). Boraiko (1982), updates *National Geographic* readers and concludes that computer chips will alter individuals' self-images. Boraiko suggests, "Apes that master sign language and use tools have already shaken the idea that to *have* ideas is to be human, a view likely to decline even further if machines too begin to think" (p. 456). Later Ward (1989) contributed an enthusiastic article to *National Geographic* that says,

> A technological prodigy fueled by society's expanding supply of computing power, computer graphics can reduce millions of numbers to a form readily accessible to human comprehension.... Anything that can be imagined can be imagined in exquisite detail and in forms that can be examined, dissected, studied, and enjoyed from any angle, in any color, with any magnification. (pp. 720-721)

Malina (1989) extends such enthusiasm to suggest,

> The computer has the potential to extend aesthetic issues into a number of totally new domains and eventually to connect directly with the human brain. At some point the computer will allow one to bypass, or supplement, the existing human senses that have formed the bases of all the arts. (p. 68)

Art teachers need a deeper understanding of the technology to avoid such unfounded fear and exaggerated enthusiasm.

Computer graphics evolved from scientists who aim for pragmatic ends without consideration for aesthetics. Their imagery is valued for its ability to communicate, educate, or achieve utilitarian ends. For example, fascinating images of moons, planets, and stars distributed to the mass media by NASA originate as numbers but they are presented as visual information. There are no "pictures" as such, only readings from instruments in satellites. These images came from data manipulated by programs - programs written by the same scientists who made the instruments. Brilliant views of Mars and Jupiter were not translated by human eyes and minds, they were designed by scientific theory and interactive computer graphics. The technology makes animated images of abstract mathematical surfaces as easily as it makes images from numerical data measured from living human organs or from the planets of the solar system. Recent techniques such as ray-tracing, fractal curves, and particle systems show how development continues to be a byproduct of scientific research and commercial development. Their products can be a great boon for art-makers if digitized imagery is understood in traditional fine art terms and as a part of Western cultural heritage.

For art teachers, it is necessary to determine how and why the increasing use of digitized imagery is changing the reality that is art, to see the scientific "realism" in the software and hardware used and, to weigh carefully the implications of the cognitive approach that is necessary. It is necessary to understand the pervasive use of this type of imagery in pop-music videos, arcade games, commercial art, and animation since this will, in part, determine what art interests students in the classroom. As Bowers (1988) says, it is important to understand, "how the educational use of computers influences our patterns of thinking, and thus contributes to changes in the symbolic underpinnings of the culture" (p. 3). Or, as Franke (1986) writes,

> Since our means of expressing ourselves is closely related to our way of thinking, we are better prepared to register linear relationships (e.g., chronological and causal) than two-dimensional or three-dimensional relationships, access to which is more difficult for us. The latter can better be described by pictures. Thus, the existence of image-created systems increases our means of expression and of imagination. Changes in our way of thinking must certainly be thought of as a long-term effect and should not be overlooked despite the more immediate modifications in behavior because of technology. (p. 119)

Western culture focuses on the sheer technical ability to produce numerous novel images. However, this is a complex, two-way influence such that technologies deeply embedded in the culture are not easily controlled. As Jones (1989) says,

> conventions of cultural reality embedded in hardware, software, and mental constructs of human participants may inhibit or preclude development of some modes. Conscious awareness of these conventions and constructs reduces their power to influence human behavior. Computer graphic algorithms based upon laws of optics for depiction of light sources, reflection, transparency, etc. and upon laws of physics for force and motion and upon medical and biological research for depiction of living forms are based upon the philosophical premises underlying scientific realism. (p. 35)

Many technologies such as photography and electronic writing are being integrated into the complex cultural fabric of everyday life as magazines, street and shop signs, candy wrappers, newspapers, books, and so forth until they disappear as distinct technologies and becomes indistinguishable from culture as a whole. However, the disappearance does not stem from the technology itself. It must be understood as human psychology; in the way human beings think about visual information and behave in particular circumstances. For example, a pervasive use of electronic word processors is replacing other ways of writing the same way digitized imagery replaces other imagery in homes, schools, offices, and the mass media. As Heim (1987) says, "Word processing is no longer a brand name but the name of a cultural phenomenon" (p. 6). Computer graphics dominates image-making in the same way word processing dominates writing.

There may be an emergence of a new aesthetics and a new way of evaluating art but exactly what this is, is not at all clear. Moving from an aesthetic based on interaction with valued, autonomous aesthetic art to experiences with more cognitive, fleeting experiences of digitized art, means changing the long-standing tradition that has been an important part of Western culture. It would be a shift from valuing work done by human hands and the appreciation of the unique qualities of such art to valuing the sequential, cognitive effort that overshadows manual skills in computer graphics. Depending on the philosophical framework this may be a stark shift or, for those who see all art-making as a form of problem solving for example, it will simply continue the evolution. This is Hubbard's (1991) view as he says, "the commitment - the raison d'être - of visual art consists of active problem solving, that is, in the production and manipulation of images" (p. 11). It may also be an increased valuing of art as a means of socio-economic communication where it is the tasks of the image-maker to provide messages. Such philosophical musings are outside the scope of this thesis but, fortunately, the long-standing Western tradition suggests art will to continue to be an important part in culture. As Franke's (1987) optimistically suggests,

> The elements of art are data, i.e. immaterial components. Even though this statement may sound rather somber, it does imply that art is not a material but rather an intellectual process.... The artist using a computer depends on the hardware and software accessible for technological, scientific and commercial uses. Fortunately, many solutions to graphic problems are designed so universally that they can also be used for esthetic applications. (p. 335)

In conclusion, the theses answers three main questions:

First, what is the nature of digitized art and how does it differ from other art? The arguments show that computer graphics is a powerful cultural influence; a scientific-commercial product that defines art images in terms of numbers and algorithms. Digitized images contrast with traditional "analog" fine art where originals are distinguished from copies and access is more difficult and less transparent to art-makers.

Second, are individuals' values influenced by digitization in a way that differs from the way they are influenced by other imagery, and, if so, how? Whether seen as a tool, medium, or a way of acting on things in the world, computer graphics will necessarily present a technological influence that changes individuals' world-views.

Third, what are the implications of making and studying this technology in schools and, if it is included, how should it be used? It can provide educationally worthwhile experiences in its own right and demonstrate the influence of such technology in broad terms. However, there should be overt awareness of the way its unique characteristics amplify and reduce some aspects of the experience and how it can be integrated into a broader visual arts education.

Footnotes

1 The thesis will not explore the impact of technology and mass media such as television in detail but there are those who argue that the influence of Television is not all that important. For example, Gans (1974, p. 31) writes, "... there is no evidence that the vast number of Americans exposed to popular culture can be described as atomized, narcotized, brutalized, escapist, or unable to cope with reality." And, "Television and other media simply do not play that large a role in most children's lives; the actions and attitudes they learn from parents and peers are far more important." (p. 33).

2 For Example, *School Arts* Vol. 87(3), Vol. 86(4), Vol. 84(6); *Art Education*, Vol. 36(3) and Vol. 38(2).

3 Burnaby's elementary schools use *SuperPaint* (a combination object-oriented drawing and bit-mapping paint program. *Lightning Paint* (a simpler monochrome paint program) is also used. More sophisticated software such as *ClarisWorks* and *FreeHand* are used in high schools. (Information from Education Center - May, 1994). New Westminster Secondary uses an Amiga System Graphics package for high-end work with sophisticated paint and animation software. They also use *Electronics Art* software for PCs and draw programs ranging from *MacDraw Pro* to *Adobe Illustrator* on Macintoshes. Paint programs include *SuperPaint* (including the color version), *MacPaint*, and *Studio 24*. In elementary schools, *DeluxePaint II* (PC) is used for simpler student art work. (Information from consultant/support resource - May, 1994). Richmond schools use *MacPaint* and Claris products (Information from Resource Center May, 1994). Most Vancouver elementary school use *KidsPics*, *SuperPaint*, and *ColorPaint* while secondary schools use product such as *CorelDRAW*, *FreeHand*, or *Illustrator*. (Information from technical support and training center May, 1994)

4 There are important issues that are not explored in the limited scope of the thesis including multi-cultural and feminists perspectives on technology such as computer graphics.

5 Computer graphics technology is seen as a means of achieving other curricular ends. The terms *technological literacy* and *technological education* are used in literature that deals with changing traditional industrial arts from a study of materials like metal and wood to a study of technological concepts, processes, and systems. For example, *Journal of Industrial Teacher Education*, 1989, Vol. 27(1). *NASSP Bulletin*, 1989, Vol. 73(519). *Science Education*, 1989, Vol. 73(4). p391-404 Jul/89. *Technology Teacher*, 1989, Vol. 48(5).

6 The bias expressed by Holmes is tempered by the overt intentions of the illustrator and he says, "The value of the picture, as opposed to decoration, is to help people understand. But, if the picture takes over and obscures the information, then it would be better not to have it at all even if you risk losing the reader." (Ibid, p. 21). This priority of content and information is the basic bias shared by most commercial and industrial developers.

7 For example, *Art Gallery* is a CD-ROM disk from the London National Gallery with 2000 works and information about the artists.

8 Gans (1974) and Adorno (1991) respectively, use the terms, *popular arts* and *culture industry* to avoid the pejorative connotation of *mass culture*, a term for non-aristocratic Europeans who today would be the poor, lower, or working class members of society.

9 Marcuse's argument attacks the contemporary notion that science is an epistemological superior mode of thought with a monopoly on truth; it is a way of seeing science as cultural construct.

10 Waddington (1970) explores the way technology and scientific attitudes affect the content and style of such areas as Cubism, the Bauhaus, Calder's mobile art, and Giacommetti's exploration of motion. Kern (1983) discusses the period from 1880 to 1928. Pelfrey (1985) starts with Greeks art and technology and traces the link between art and technology to computers. Davis (1974) provides a number of illustrations that show how computers have been used during the early years to explore new artistic expressions - including well known early works such as Charles Csuri's 1967 illustration *Sine Curve Man*, a computer drawing of human face based on sine curves (p. 96).

11 Clignet documented changes in art from the early Greeks through the Renaissance to the modern era and shows how artists like Dürer, Delacroix, Turner, Constable, Monet, and Renoir were influenced by materials and tools.

12 Authors like Turner (1992), Luckiesh (1965), and Clark (1986) have explored such relationships in great detail.

13 The programmatic nature of the technology is most apparent in the way image makers are forced to make "tradeoffs" at all times. That is, the finite capacity of all computers makes segmentation of image making programmatic and, at times, forces a hierarchy on "tools" or commands. All software makes "tradeoffs" in one way or another. For example, *QuickTime* (digitizing movie software product that "grabs" frames) displays video at about six to twelve feet per second (extremely poor quality movement compared to TV with thirty feet per second) on a rectangle that's 160-by-120 screen dots (pixels) square (one sixteenth of a regular screen) and compresses the file by discarding redundant information as it analyzes the color information in the sequence. (Pogue 1992). It is a matter of tradeoffs between quality for color, frames per second, larger windows, faster motion against disk space or processing power.

14 An article in the same magazine by Fenton (1990) describes and rates fifty of the most common clip-art products on the market with everything from maps to medical illustrations showing how the technology lends itself to reusing existing image in many fields.

15 Wohlwill and Wills studied 10 to 12 year old elementary school children. Freedman's study included two elementary and one high school art classes. Two studies by Freeman and Relan (1990 and 1992) were carried out with university students using *Deluxe Paint II*. All the research by Freedman, Relan, Wohlwill, and Wills was based on an analysis of the students' reactions in controlled environments. It would be equally important to determine how and why such

technology is introduced into the classroom. This could allow us to look at the cultural forms that are imbedded in the technology, the biases that are amplified, and determine if these cultural forms are what we intend to pass on to students. It will also be necessary to determine if the bias of computers through the way software is developed by programmers dominates to the extent that research questions are structured to suit computers rather than researchers using computers to suit the research. This was the case for some computer-assisted learning software used in other areas of the curriculum. As Anderson (1985, p. 224) says, "Our review of how computers, television and video discs are being used for instruction has revealed deficiencies in content design. Courseware written by programmers tends to be technically sophisticated but instructionally deficient."

16 For example, Bolognese's (1988) book, *Mastering the Computer for Design and Illustration,* shows how to integrate computer design in art, craft, and design. Similarly, Winograd and Flores (1986) discuss computers in, *Understanding Computers and Cognition: A New Foundation for Design,* and write, "All new technologies develop within the background of a tacit understanding of human nature and human work. The use of technology in turn leads to fundamental changes in what we do, and ultimately in what it is to be human. We encounter the deep questions of design when we recognize that in designing tools we are designing ways of being" (p. xi).

17 Harry Broudy (1988, p. 180) says that in, "... general education the skills of production of art objects are secondary to their use in developing the skills of aesthetic perception." And, Edward Pope (1988, p. 332) says that, because of computers, it is possible that education in the arts can focus less on concrete production and, "... a student's education must focus more on the critical investigation of feeling and understanding during the process of art making, and art viewing, and less on the production of material art objects."

18 This is not a universal view and Roszak (1986) says, "Undeniably, some kids click with computer. The emphasis, however, belongs on *some* - as in the phrase, *some* kids click with violins, or *some* kids click with paintbrushes. But there are no millions being spent to bring violins or paintbrushes into the schools. Initially, there was a simple justification for favoring computers over violins in the budgetary priorities of the schools. It was embodied in the catchphrase *computer literacy* - a seemingly undeniable necessity in the Information Age" (p. 49).

Appendix: Computer Graphics

> Graphic stations are still in infancy. On 2-D graphics, users of schematics editors, VLSI layout and mechanical drawing are limited by screen resolution. Progress in this respect will be slow. 3-D graphics are improving rapidly, but the requirements for realistic scene and technical objects representation is very high, especially in the case of animation. Many competitive circuits and stations will appear in the future, and there will be portable low cost, flat screens, 1024 by 1024 colored 3-D visualization stations before the end of the century. (Nicoud, 1990, p. 11)

Those intimately involved with computer graphics have their own language and terms such as *resolution*, *graphics*, or *animation* are used in contexts that can be misleading for people from other fields such as art education. For example, the quotation is cryptic unless terms such as *screen resolution*, *schematics editors*, *VLSI*, *flat screens*, and *1024 by 1024 colored 3-D visualization stations* are understood. Teachers will be faced with such terminology whenever they use computer graphics and evaluate the offered features of the hardware and software that is available. An analysis of these features may be quite detailed and include such considerations as noting that *SuperPaint* is both a *bit-map* drawing program and an *object-oriented* drawing program; that there is a 612 x 792 grid with 175,104 *pixels* on a standard Macintosh display and 342 scan lines to create a *raster* display; that *SuperPaint* is 150 or 300 dots per inch (DPI) and uses *PostScript*; that *Adobe Illustrator* can print or save in *Illustrator*, PICT, or ESP format; that the Macintosh shades by *dithering*. These terms comprise only a portion of the "jargon" used to talk about Macintosh Graphics. This shows the difficulty that a novice computer user is faced with when choosing the software; similar jargon and difficulties are also faced when choosing and combining hardware and software. Even familiar terms such as *3-D graphics* or *animation* carry assumptions understood by technologists and scientists who use such terms within tightly defined parameters that apply only to digitized imagery and computer animation. This appendix explains some of the more cryptic terminology. Words shown in capital letters and bold faced type such as **COMPUTERS** or **COMPUTER GRAPHICS** are defined in a few short paragraphs with comments on pertinent technical terms that further clarify the area. The topic of computer graphics as discussed in the thesis is accessible to non-experts through a few key terms. For example, the quotation predicts that 2- and 3-D graphics will continue to be limited in the short term by the number of finite points (pixels) that are accessible on screens and this comment is followed by the suggestion that affordable specialized graphics workstations with more addressable pixels, more memory, and faster processors will soon be available.

COMPUTERS: A functioning computer always includes hardware and software. The hardware includes the central processing units (CPU); keyboard, mouse, joystick or other input devices; hard disks, tape drives, or floppy disk drives for storing data; and output devices such as **SCREENS**, **PRINTERS**, or plotters. The software includes programs on the Read-only-Memory, disks, or tapes which contain instructions for a computer's operation. Common software includes such programs as *Microsoft Disk Operating System* (MS-DOS) for IBM microcomputers and application programs such as *SuperPaint*, a proprietary draw/paint program widely used with the Macintosh.

At the heart of the hardware are the silicon chips which form the basis of all computing. They come in various configurations which translate into different CPU's. The IBM microcomputers and its clones such as Compaq or Tandy, use 286, 386, or 486 chips. Apple use the 68000 series chips. Motorola introduced the 68000 chip (about 68,000 transistors) in 1979 and it is still used in the Macintosh Classic. The higher the number, the more powerful the chip is. For example, a 68030 chip has over 300,000 transistors while the Apple Quadra's 68040 chip has over 1.2 million. Transistors are minute gates of silicon, a semiconductor that either blocks the path of current or allows it through to form on/off positions (digits 1 and 0 are the basis of all computational operation). Speed is in megaherz, MHz or millions of *clock cycles* per second. Speed is important for graphics where it makes a difference in image quality because no instruction can take less than one clock cycle and that makes it a delimiting processing factor. For example, at 8MHz, a clock cycle lasts 0.125 millionth of a second; at 50MHz, 0.02 millionth of a second. This means an image will appear clearer and more realistic of it is shown on a "fast" computer graphics workstation. The speed of operation and transmission is measured in nsec (nanosecond) or psec (picosecond). The nanosecond is a billionth of a second, and a picosecond is a trillionth of a second (a second is 9,192,631,700 cycles of the frequency associated with the transition between the two energy levels of the isotope cesium 133). Finally, some chips have a cache for storing instructions and data which speeds up the operation and some chips have the ability to do multiple instructions at once. Thus, a 25MHz 68030 chip limited to 4 instructions at once is slower than a 25MHz 68040 chip that does 6 instructions at once.

A binary digit (bit) is the smallest unit describing an image or any other digital information. A bit has only two possible values, on or off, 1 or 0. A byte is the basic unit of information communicated within the computer and peripheral devices; it is composed of several bits. A byte typically has eight bits but different computers could have 8-bit, 16-bit, 32-bit, or 64-bit words. There are 8 bits to a byte giving 256 permutations. Related terminology includes: (KB) kilobyte - a thousand bytes), (MB) megabyte - a million bytes, and (GB) gigabyte - a billion bytes. These numbers are approximations - a megabyte is precisely 1,048,576 bytes rather than one million bytes. Transmission of data is discussed as "baud rate" or number of bits per second (bps). With glass fiber communications networks it is possible to transmit a billion bps over long distances.

All software can be reduced to bits (on or off, "0" or "1" settings) that are used as the building blocks of instructions and images. These bits may reside in ROM or RAM. Read-only-Memory (ROM) stores basic instructions that initiate other software and processes on the computer while Random-access-Memory (RAM) is the active, on-line storage of calculations in real-time computing. The information contained in RAM is lost when the computer is turned off and important information is stored on a hard disk or floppy diskette where the data can be retained. RAM is discussed in megabytes where one byte is usually one character, a single letter or number.

<u>SCREENS:</u> Virtually all monitors outside scientific laboratories are digital. Screen images are called *soft-copy* (print is *hard-copy*). Screens are also called monitors, CRTs (cathode ray tubes) or a VDTs (video display terminals). They are either monochrome (single color) or video graphics array (VGA) for multiple colors. Super VGA screens (SVGA) give better resolution and they can be enhanced by a memory card to allows more color combinations. For example, upgrading a 16 color SVGA to 256 colors on a 1024 x 768 color dpi (dots per inch) screen is considered a good model. Most color screens are RBG (Red/Green/Blue). Others are National Television Standards Committee screens (NTSC).

There are some differences in the screens commonly used for desktop computers and those used with portable technology. Flat screens are Active-matrix Liquid Crystal Displays (LCD) that are widely used in portable computers. Active matrix screens are LCD panels that have transistors at all (*x*, *y*) grid points (as opposed to lines of information controlled by transistors) to change the state of the crystals quickly and control the degree to which the state has been changed. The latest provide brilliant colors and need little power. For example, some computers use a thin-film transistor (TFT) LCD with a 640 x 480-pixel VGA screen; a 10.4 inch screen with over 300,000 pixels. These screens are based on organic liquid-crystal molecules that can be aligned using an electric field. The intensity determines alignment and the amount of polarized light from a fluorescent bulb that passes through a color filter to a liquid-crystal panel of TFTs etched onto a glass plate or amorphous silicon. There are usually three sub pixels used per pixel of color, one each for the red, green, and blue filters. These screens are fast, 30-50 msec. response time compared to 100-150 msec. for conventional super-twist screens, but still slower than the CRTs at less than 10 msec.

PRINTERS: Computers connect to dot-matrix, ink-jet, laser printers or other output devices through parallel ports while serial port connect them to modems that may link up with other computers or output devices. Some conventions are built into the printers. For example, Postscript printers have an internal "engine" or chip to interpret images in a device-independent fashion. The quality of the printed image is dependent on dot size and the number of individual dots that can be addressed. Most printers are still black and white only but color laser printers are becoming increasingly efficient and affordable. They usually put down dots of cyan, magenta, yellow, and black dots and let the viewer's eyes mix the color. They achieve varying degrees of fine detail by having limited size of dots. A high-quality color printer such as a Hewlett/Packard (HP) *PaintJet XL300* lists at $3,500.00. More expensive products such as a *RasterOps CorrectPrint 300,* which cost about $12,000, use dye-sublimation techniques to achieve near-photographic quality images (Pricing varies greatly, quotations are from the fall of 1992). These printers place translucent color dots of varying sizes on top of other dots to build subtle shades and colors. For example, a *CorrectPrint* lay down

256 sizes of dots at a rate of 300 per inch, a quality of print visible only with a strong loupe.

COMPUTER GRAPHICS: Foley, van Dam, Feiner, and Hughes (1990, p. 2) state, "Computer graphics concerns the pictorial *synthesis* of real or imaginary objects from their computer-based models." This defines many digitized image-making technology including specialized techniques such as *image processing* or *picture processing* which includes digitized imagery such as aerial surveillance photographs, chromosome scans, X-ray images, or computerized axial tomography (CAT) scans. *Image processing*, emphasizes analysis and reconstruction of objects done in areas such as *computer vision, image enhancement, pattern detection and recognition, scene analysis, positron emission tomography* (PET scans), *nuclear magnetic resonance* (NMR), *magnetic resonance imaging* (MRI), and *optical character recognition* (OCR). Terms such as, *analog media* and *analog art*, are generally used to distinguish digitized imagery which are fundamentally numbers and algorithms from traditional art imagery such as drawings, paintings, etchings, or photographs where imagery is not generally viewed, manipulated, and described at a non-physically-accessible level. That is, analog media is defined through such terms and entities as lines, shapes, textures, colors, and so forth; individual entities that are continuously blended and merged in a way that does not allow access with the same speed, accuracy, and diversity as the non-physical numbers and mathematical algorithms that constitute digitized imagery.

Virtually all computer graphics developments came about during this century after the emergence of the first electronic computer (ENIAC) in 1946. In the late 1940s, scientists such as Ben Lapofsky and Herbert Franke first used analog computers and voltage-controlled oscilloscopes to make art. Oscilloscopic Art, photographed time exposures from screens, is considered the first **COMPUTER ART**. In the late 1950s, digital computers became important in scientific, military, and academic institutions and the technology was gradually incorporated into the art worlds. Artists first used the technology in conjunction with their interest in kinetic sculpture and other art work with light, motion, and noise. By the late 1970s, **RASTER GRAPHICS** were common. This meant art-makers could use computer graphics outside the narrow confines of the expensive mainframes in military, academic, and scientific institutions. Raster graphics and microcomputers allowed the sophisticated, three-dimensional, colored, shaded, textured images with reflections and transparency that are taken for granted today. The Macintosh and other PC's appeared in the 1980s and contributed to the tremendous increase of computer graphics in business. Microcomputers also opened the field to artists who used interactive systems to simulate drawing, painting, and photography techniques. However, most commercial software was developed in order to provide the primary users, the scientists, engineers, and technicians, with an ability to explore the possibilities of objective realism; making and studying simulation of a visual, physical world by mathematical algorithms.

An important part of computer graphics in most fields is digitization of analog data or images through some form of sampling techniques that "approaches" the analog image by assembled pixels that make up the "sampled" image. The term *scanners* is used to describe the equipment commonly used in schools and business to "scan" a two dimensional image into a bit-mapped or object-oriented digitized image. Similarly, *frame grabber*, is a term used to describe the commercial equipment in common usage that isolates a "frame" from analog video or film footage as a digitized image which can then be manipulated as a separate "still" used in computer animation techniques. Current areas of interest for developers include **SOLID MODELING, COMPUTER ANIMATION, FRACTAL MODELING**, and **COMPUTER GRAPHICS COLOR.**

COMPUTER ART: *Computer art* can be a subset of the drawings, illustrations, charts, graphs and diagrams that are part of computer graphics. Computer art is the imagery intended to provide aesthetic interest as opposed to that meant primarily for design or utilitarian purposes. However, all digitized images are comprised of the same building blocks of bits and bits are assembled into **BIT-MAPPED** or **OBJECT-ORIENTED** images as numbers or mathematical algorithms.

Oscilloscopic Art was followed by simple pictures drawn on output devices through large mainframe computers costing from $100,000 to several million dollars. Images were usually made on commercial computer driven plotters or large line printers without interactive capability. Dietrich (1986), Benthall (1972), and Davis (1974), provide examples of such "classic" art as Kenneth Knowlton and Leon Harmon's 1966 reclining nude. Knowlton and Harmon used a special camera to "scan" a photograph of a reclining nude by converting the camera's electrical signals into numeric and electrical symbols. These were manipulated by the computer and "drawn" on microfilm.

Gyorgy Kepes, a major factor in the development of computer-mediated art, exhibited photography at the MIT art gallery that led to his series of influential books in the 1960s, *The New Landscape in Art and Science*. Kepes followed earlier reactions to technology such as Frank Lloyd Wright and Louis Sullivan who changed architecture, Hermann Muthesius and Walter Gropius who explored new materials at the Bauhaus, and artists such as Naum Gabo and Alexander Calder who explored kinetic sculptures and new technologies. As Davis (1974) writes, "The evidence of these works, all executed between 1913 and the mid-1930s, indicates that art was beginning to involve itself with light, motion, noise, film, total design, architecture, and theater, in fact as well as theory" (p. 31). Gyorgy Kepes organized an exhibit at Harvard's Carpenter Center for the Visual Arts, *Light as a Creative Medium*, in 1966. This led to the opening of Kepes' Center for Advanced Visual Studies at MIT in 1967.

At the same time, Robert Rauschenberg and Swedish engineer Billy Klüver founded Experiments in Art and Technology, Inc. (EAT). Robert Whitman and James Turrell used laser light in their 1967 art shows and by 1969 the first substantial Laser Art exhibit was held a the Cincinnati Museum of Art. Architect Nicholas Negroponte at the

MIT Media Laboratory, used computers for complex design problems. His *Architecture Machine* was shown at the Jewish Museum in 1970 as one of the computer robot exhibits. Other artist-scientists were involved in formal collaborations and projects initiated to explore the phenomena associated with visualization of acoustics and binocular vision such as: *Cybernetic Serendipity* show at the Institute of Contemporary Arts, the 1970 *Software* exhibit at New York Jewish Museum, and Maurice Tuchman's five-year effort (1967-1971) that led to the Los Angeles County Museum's *Art and Technology.*

The interactive software we now associate with computer graphics was made possible by the seminal work by Ian Sutherland at MIT in the area of interactive computing. His 1963 Ph.D. thesis, *Sketchpad*, showed how interactive computer graphics was both possible and practical. By the mid 1960s, interactive displays were in common use and practical implementation systems with Sutherland's data structures and interaction techniques were initially developed at Harvard University in 1968. This type of development led to the many exciting computer graphics projects of the next thirty years.

There were an estimated 90,000 computers throughout America, Europe, and Japan (70,000 in the US) by the end of the 1960s. During the late 1960s and early 1970s many important developments emerged. For example, GM used the first computer-aided design (CAD) to produce auto parts; Jet Propulsion Laboratories in Pasadena translated numerical data from the Mars landing into "live pictures" for TV screen; Sutherland developed systems with headsets for virtual reality; and Fractal geometry was invented by Mandelbrot. In the 1970s, American films became a force in computer animation and other special film effects. George Lukas founded Industrial Light & Magic, in San Rafael, California in 1975. A year late Steve Jobs and Steve Wozniak built the first Apple Computer in their garage and began the revolution that allowed a large number of people to work with computer graphics. Pentel's *Futureworld* (1982) commercial was the first completely computer-generated advertisement and *Shatter* (1985) was the first comic book with text and images made by the same computer. Notable early developments in the entertainment industry include Michael Crichton's 1981 seminal film, *Looker*, that introduced three-dimensional computer graphics to feature films, Disney Studio's 1982 film *TRON,* and Lucasfilms, Ltd. productions such as *Star Trek II* and *Return of the Jedi.* These films changed the film and animation industry and they raised the expectations of audiences by presenting progressively more sophisticated special effects. Recent films that use such techniques includes the *Star Wars* trilogy, *Backdraft, Willow, The Rocketeer, Hudson Hawk, Terminator 2, Star Trek 6, Memoirs of an Invisible Man,* and *Hook.* Garcia (1991) describes some of the most innovative techniques such as "Morphing" and "Make Sticky" used in *The Terminator 2* to break down the film image into complex numerical codes that can be manipulated. Thus, the robot T-1000 changes into human form and live action combines with computer-enhanced three-dimensional image to provide the illusion of walking through steel bars.

OBJECT-ORIENTED (Vector Graphics): Vector graphics is an efficient means of building a two- or three-dimensional object based largely on lines and point on a Cartesian grid that can be manipulated quickly and easily by mathematical algorithms. Images are defined through a few algorithms rather than by individual pixel manipulation. Such images change in size without losing resolution and they are more cost effective in processing power and storage requirements than raster graphics. This has great significance for those who are not primarily concerned with the aesthetics of the image because it increases the possibilities for efficient animation, modeling, or communication.

BIT-MAPPED (Raster Graphics): In computer graphics, the bit is the smallest unit of information and a bit-map is simply the computer memory where each bit provides one-on-one information for a pixel (smallest addressable unit on the computer screen). The quality of images, in terms of such things as the amount of jaggies depends on the number of pixels. Since the pixel is the smallest addressable dot, the edges that are not vertical or horizontal will appear jagged. That is, a diagonal line look like a series of steps if it is examined closely and these uneven edges of straight lines on the raster display are called *jaggies.* A great deal of development intends to eliminate this effect by a variety of techniques called *antialiasing.*

Bit-mapped graphics is the depiction and manipulation of images on a computer screen where each individual pixel can be changed or controlled by the image-maker in real-time. In the simplest terms, a picture can be composed of black and white dots represented by the digits 1 or 0. Color requires more bits per dot. 2 bits for 4 colors or grays, 4 bits for 16 colors or grays, 8 bits for 256 colors or grays, 12 bits for 4,096 colors, 16 bits for 32,767 colors, and 24 bits for 16.8 million colors in a photo-realistic image. A 32 bit number can have a value between 0 and 4,294,967,295 while a 16 bit number ranges between 0 and 65,535. This shows why modern graphic work stations need to be 32 bit machines (32 bits per cycle). Bit-mapping requires a high usage of computer resources compared to object oriented graphics that only describes essential image components through horizontal and vertical coordinates of lines and areas.

<u>COMPUTER GRAPHICS COLOR:</u> Color parameters are standardized and used with conventions such as the Munsel color-order system. Conventions are published as sets of standard colors organized in three-dimensions as hue, value-lightness, and chroma-saturation. Computer graphics monitors use RGB (additive Red, Green, and Blue primaries for electron beams). Images are made by scanned electron beams focused on non-persistent phosphor-coated screen at a rate greater than 70 Hz (50 Hz for color). CMY (Cyan, Magenta, and Yellow primary subtractive filters from white light) for standard printing.

<u>COMPUTER ANIMATION:</u> The term *computer animation* is not always qualified by the word "computer" and often just referred to as "animation" but these terms are used interchangeably. Computer animation is used in scientific illustration, commercials, and entertainment for processing generated digitized images quickly

enough to provide an illusion of motion that matches the quality of video or film images. For example, in the entertainment industry, the computer may simply take a number of digitized frames made in some way and present them in sequence, it may use a few key frames that are then merged by algorithms to produce a smooth sequence, or the total scene and all movements may be generated by algorithms. HumanCad's software, *Mannequin*, which uses human models in drawings and films or Autodesk Inc.'s *3D Studio* that is used to animate scenes for film makers before they are shot are examples of modern animation software in common use.

Good quality animation or simulations require a tremendous amount of processing power since it takes at least fifteen frames per second to produce relatively smooth animation. Twenty-four frames per second is required for professional work. It is complex and resource intensive work. For example, Bloomer (1990) notes how a 37-second sequence in *Return of the Jedi* took four months to produce. Similarly, Goodman (1987) tells how, "The twenty-five-minute, ominously lifelike fight sequence in Lorimar's film *The Last Starfighter*, for example, required over a quadrillion calculations" (p. 12). The Cray, a powerful supercomputers used by NASA and other large scientific institutions performs at over 200 million floating-point instructions per second. Still, it requires between three seconds and ten hours to generate a second on a computer screen depending on the complexity of the image. However, this technique is becoming increasingly pervasive because, even at $200 to $2,000 per minute, computer animation is half as expensive as hand-animation.

The increasing influence of computer animation technology has been a strong influence on all computer graphics development in recent years. This is one area where the limits of technology and human vision are closely linked and an area where we clearly see the way standards are both enhancing and biasing the software and hardware in every respect. There is a need to facilitate the human eye which determines the quality of moving images by the number of frames per second for digitized images and the number of scan lines for video images. This means the technology is forced to meet very specific criteria but there is a corresponding acceptance of the unique form that is perpetuated by the "models" and "rough" images of video games and other popular digitized imagery.

The increasing use of International Communication Satellites in the 1960s to send TV images around the world resulted in a great deal of raster graphics technology development to merge digitized images and video. The need to merge these two worlds create much of the demand for more speed and detail in digitized imagery and, at the same time, the increasing use of more efficient digitized models to represent reality. The emphasis is apparent in the hardware as well. For example, my latest Quadra 840AV supports the three major video standards used in the world (NTSC, PAL, and SECAM) making it a truly international animation machine. NTSC (National Television Standards Committee) is the 525-lines, 60 times per second protocol used by the USA and Japan. France uses SECAM which is a variation of PAL, a 625-lines, 50 times per second protocol used by the rest of the world. The perceived need for higher resolution is affecting the TV industry also. For example, a high-definition television screens (HDTV) uses 1,125 horizontal lines compared to the conventional 525 lines (by comparison, a standard 35mm film is at least the equivalent of 2,000 lines on a TV screen) and there is strong contention between HDTV and fully digitized television technology.

SOLID MODELING: Software such as *Infini-D, MacRenderMan 1.1, Alias Sketch 1.0.2, ElectricImage Animation System 1.03, MacroMind Three-D 1.0, MacTOPAS, Presenter Professional 1.1, Ray Dream Designer 2.0, Sculpt 3D/4D,* and *Stratavision 3D* provide a similar set of features through the compartmentalizing, step-by-step process required to make an image. For example, these packages rely on a series of steps that allow such actions as "lathing" where a 2-D outline can be rotated 360 degrees to create a 3-D shape, "spline-based modeling" that adjusts the form of a 3-D object through control points, "sweep surfaces" that sweep a 2-D outline circularly around a center point while resizing and moving the outline in 3-D space, or "drilling" where a 2-D outline is used to drill a hole through a 3-D object so the object contains an actual hole and not just the facade of one. Such software offers features from commands for such things as texture mapping or rendering techniques such as ray tracing that are broken into smaller sequential processes. Texture mapping is segmented as spherical, cubic, cylindrical, planar, or bump mapping. Similarly, light control is applied as ambient light to define color and darkness of the darkest areas for night or day effects, radial light for a central light source, distance light for light coming from one direction, and spot lighting for one intense beam of light. Solid modeling relies on Boolean operations that provide basic ways to create images through joining of shapes or using the area where shapes overlap. Regardless of the software and hardware, the same set of Boolean algebraic operators with similar algorithms are used.

Hidden line/surface removal is important because many scientific and commercial application use solid modeling. There is a lot of emphasis on the development of simple but elegant algorithms for realistic shadowing and shading. This is a powerful technique that requires a lot of memory because there is a need to store each pixel and compare the distance to a viewer's eye before some dots are placed and others are hidden. The technology is structured such that the "Wire-frame" models are the fastest method of viewing a 3-D object which will then be modeled or "rendered" by slower "Hidden-line removal" techniques. Some common shading techniques are categorized by the name of their originator. For example, Blinn Shading (a unique way of computing shading for 3-D surfaces through diffusion, specularity, eccentricity, and refractive indexes) was developed by James Blinn and Phong shading (using diffusion, specularity, and shininess) was developed by Phong Bui-Tuong.

Ray tracing is a computing intensive method of simulating the way "nature" operates. It was developed in the late 1960s to simulate rather than approximate human vision. It is the scientific explanation of reality. A fictitious source of light from points in the image raster where an object resides is calculated to move in a straight line to the operator's eye (it is traced with or without reflections from other objects where it may be reflected or absorbed to a specified degree). This technique can include specular and diffuse reflections on drawn surfaces by invoking bump mapping, chrome mapping, or reflection and transparency mapping techniques to simulate various textured and smooth surfaces. Franke (1987) says, "Since transparent or reflecting objects cause particular problems, they frequently occur in images designed to demonstrate the high degree of quality that can be achieved" (p. 336). A much slower, more elaborate method of tracing called, Raydiosity, allows uncanny realism through the integrated depiction of illumination, surface texturing, reflectivity/refractivity, atmospheric conditions, and so forth. In this area, developers make many assumptions about human vision and provide short-cuts to make the process effective.

FRACTAL MODELS (fractal curves): Fractal Geometry is often used to deal with complex functions that classical geometry fails to describe and it does so with a small number of parameters that can result in great visual complexity. Fractal geometry was introduced by the French mathematician B. Mandelbrot as a means of simulating irregular, broken functions that appear frequently in nature such as rivers, clouds, coastlines, mountain ranges, vegetation, or trees. These "natural" functions are continuous but they are never smooth and, therefore, they cannot be dealt with by classical geometry. Mandelbrot (1989) says, "During the 1970s it was my privilege to conceive and develop fractal geometry, a body of thoughts, formulas and pictures that may be called either a new *geometry of nature* or a new *geometric language*" (p. 21). This is an important technique that allows many impressive special effects and detailed images. Mandelbrot adds, "To draw the simplest fractal picture 'by hand' would have been feasible in principle, but would have required many person-years and would have been ridiculously expensive. (Ibid). Fractal sets are generated by a few parameters to specify frequency, dimensions, and size. This means synthesized object can be made with significant data compression. The simple geometric shapes are equally complex in detail and overall form and any piece of a fractal can be magnified to the same size as the whole and still look just like the whole (either exactly or with a few limited deformations as required by the application). However, fractals allow a simulation of an organic image by magnification and repetition of a simple mathematically defined image and the repeated detail is much the same at all levels of magnification. The result may be monotonous from an aesthetic perspective. A similar technique, called a particle system, uses many small primitives (particles) to represent the volume objects. Paramount's 1982 *Star Trek II: The Wrath of Khan*, used this technique for the Genesis Demo sequence.

(Bennett 1993, Benthall 1972; Binkley 1989; Blake 1990; Bloomer 1990; Brennan 1985; Brown 1987, 1989; Buser, Radic, and Semmler 1990; Davis 1974; Dietrich 1986; Foley, van Dam, Feiner, & Hughes 1990; Franke 1986, 1987; Gagalowicz 1990; Goodman 1987; Greh, 1990; Hickman and Al-Hibri 1981; Hildebrand 1992a; Jones 1989, 1990; *Macworld* February, June, October, 1992; Mandelbrot 1989; Nicoud 1990; Norman 1990; Pelfrey 1985; Poole 1992; Prueitt 1984; Rivlin 1986; Runyan 1991; Thalmann 1990; Truckenbrod 1988; Woodward, 1980b).

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