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The Motion Picture in Science Education: "One Hundred Percent Efficiency"

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This study provides a historical overview of the development of the motion picture as a tool within the context of science education. The technology was traced from its beginning as a silent motion picture through its current manifestation in videotapes and videodiscs. The use of the technology as a teaching tool is examined in terms of the concept of scientific literacy and the means by which the motion picture helped to accomplish the goals of scientific literacy.

KEY WORDS: Motion picture; science education; scientific literacy; history of education.

In 1922 Thomas Edison made the following statement regarding the use of the motion picture in instruction:

> I believe that the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks. I should say that on the average, we get about two percent efficiency out of schoolbooks as they are written today. The education of the future, as I see it, will be conducted through the medium of the motion picture. . .where it should be possible to achieve one hundred percent efficiency. (Cuban, 1986, p. 9).[2]

The wizard of Menlo Park played a significant role in America's infatuation with technology, receiving several hundred patents over the course of his life. Many of his inventions and their direct technological descendants are still in use today. Also present is the attitude that technology can help us to achieve closer to "one hundred percent efficiency" in our daily tasks—including science education. Looking back from the future Edison envisioned, the goal of "one hundred percent efficiency" has not been achieved, yet technology has impacted science education in ways that scarcely could have been conceived. The film was one of the first electrical-mechanical technologies to enter the domain of education. To begin this investigation, an overview of the technology itself is helpful.

Background: Development and Adoption of the Technology

The motion picture is an excellent example of a technology that was heavily reliant on previous inventions, rather than an innovation that sprang forth fully developed. It assumed a secure place among the American public as motion picture entertainment rapidly captured people's imagination.

The Development of the Technology

The motion picture can identify its most significant technological ancestors as the camera and the projector. Applications of these simpler technologies were seen in the work of Eadweard Muybridge (Mast, 1981).

> In 1872 [Muybridge] was hired by the governor of California, Leland Stanford, to help win a $25,000 bet. Stanford, an avid horse breeder and racer, bet a friend that at some point in the racehorse's stride,

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[2]It is also worth considering that Edison's enthusiasm for the motion picture is likely related to his having invented this particular technology.

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> all four hooves left the ground. In 1877, after five years of unsuccessful research, Muybridge set up twelve cameras in a row along the racing track. He attached a string to each camera shutter and stretched the string across the track. He chalked numerals and lines on a board behind the track to measure the horse's progress. Stanford's horse then galloped down the track, tripping the wires, and Mr. Stanford won $25,000 that had cost him only $100,000 to win. (p. 11)

This first step—of capturing a series of a horse's footfalls in sequence—was in essence the reverse of the process by which the motion picture worked. Any child familiar with making a series of small drawings on the corner of a tablet, each slightly different from the previous one, and then flipping rapidly through each page has duplicated the fundamental concept underlying the motion picture. Were Muybridge's sequential photographs, projected rapidly to the human eye, they would produce the impression of a horse in motion.

The master inventor-businessman Thomas Edison took on the challenge of developing the motion picture in its recognizable form. Edison originally was more interested in documenting his previous inventions with his newest creation; the possibilities that film offered did not immediately capture his attention (Mast, 1981). As such, his interests in the media were split between a single-person viewing apparatus—a ''peep show'' device called a Kinetoscope—and a more public display forum. Edison focused primarily on the Kinetoscope. Edison's laboratories produced the earliest complete film on record in 1890. Thousands eventually were entertained by the short film *Fred Ott's Sneeze*.

Edison neglected to extend his patent on the new technology to Europe; as a result, subsequent developments were not produced in Edison's laboratories. The primary technical challenge remaining was to develop a means of projecting the images with sufficient brilliance and clarity that a group of individuals would be able to view the motion picture.

The French brothers August Marie Louis Lumnière and Luis Jean Lumnière moved the film ahead technologically. Several improvements developed by the Lumnières helped advance the motion picture: portability and creating one machine that both printed and projected the pictures. Then, by projecting a light through the lens when showing the motion picture, the images were presented in a large group setting rather than to an individual viewer (Mast, 1981). Compared with Edison's one-viewer Kinetoscopes, the Lumnières' public demonstrations of the technology were startling. Their motion picture of a train rushing into a station had people shrieking and ducking as the train came hurtling in the audience's direction (Mast, 1981).

Public Use of Technology

The motion picture rapidly assumed a status as a popular form of entertainment. Movie houses opened rapidly during the first decades of the twentieth century; by the mid-1920s, teachers were reflecting on the competition offered by motion pictures for their students' attention. By the end of the 1930s, over eighty-five million Americans attended a motion picture each week (Thorp, 1939). So pervasive a presence was the motion picture that its movement into the classroom was inevitable.

Thorp (1939) commented on the informal nature of films as instructional devices in the early years of the century:

> The enormous amount of general information absorbed by the movie going child and the painless ease by which it is retained have long been a cause of heart searching to educators. The small-town boy in Vermont or Arkansas who has never in his life been fifty miles from the farm is now quite at home on the *Place de la Concorde,* Broadway at midnight, the Himalayas, or any one of a dozen South Sea islands. He knows something about coal mining, about radio broadcasting, deep sea fishing, and bridge building . . .

The challenge faced by science educators, then, was to make the ''general information'' described by Thorpe more specific and apply it to the goals of science teaching.

Educational Advocates

As early as 1902, non-theatrical uses of film were in evidence. Early examples of educational film were ''the newsreel, the travelogue, and the scientific motion picture'' (Saettler, 1990, p. 96). Setting the stage for eventual developments in America, Saettler (1990) recounted several early examples of educational film:

> . . . by 1902 Charles Urban of London had exhibited some of the first educational films, and films with slow-motion, microscopic, and undersea views were beginning to be produced. These films included such subjects as the growth of plants and the emergence of a butterfly from the chrysalis. In . . . 1904, at the

> Marey Institute in Paris, Marey and his associates filmed the flight of insects, the locomotion of animals in water, the digestive process of small animals, and the heart in action. (p. 96)

Training individuals in the use of the technology provided an area of exposition for numerous individuals. The information presented in *Optical Projection* (Gage and Gage, 1914) resonates with contemporary readers who have been frustrated with instruction in RAM, ROM and hard drive space when their real concern is how to compose an essay with a word processing program. The Gages detailed the physics of image formation as it applied to motion picture and magic lantern presentations in the hope that

> [with] such simple and explicit instructions . . . any intelligent person can succeed in all the fields of projection; and our hope is the book will serve to make more general this graphic art by which the means of many persons can be appealed to at the same time and in the most striking manner. Furthermore we believe this art has great, undeveloped possibilities for giving pleasure, arousing interest, and kindling enthusiasm, in that it provides for the . . . demonstration of maps, diagrams and pictures of all kinds, the structure and development of animals and plants, many of the actual phenomena of physics and chemistry, and finally scenes from nature and from life, even with their natural motions and colors. (p. iii)

To achieve their enthusiastic aims, the text provided a highly technical overview of the physics of image formation and the advantages of the various technologies then available. Sadly, many of the issues that would bring an instructor to use this technology in the classroom were addressed only in the preface, yet these motivational and instructional goals contributed insignificantly to the body of the text. Care and maintenance of these expensive tools were also included, in the hopes that the technology would achieve a long and successful classroom life.

A 1920s era study (Wood and Freeman, 1931) examined the issue of using motion picture technology as a means of improving science instruction. The study compared coverage of similar science topics, with the single difference in instruction being that the experimental group had access to motion pictures to assist in the learning process. Findings indicated that only 38 percent of the control group showed the same gains as the students who were exposed to motion pictures as part of the learning process. Teachers, when surveyed as part of the study, responded that the films were

> highly effective (1) in arousing and maintaining interest; (2) in increasing the quantity and quality of the reading, project work, classroom discussion and writing; (3) in promoting a more thorough correlation of the materials on the part of the pupils; (4) in increasing the richness, accuracy, and meaningfulness of their experience; (5) in facilitating the work of the teachers in organizing the lesson materials and in making teaching more pleasant and the self-activity of the teachers greater. (Wood and Freeman, 1931, pp. 118–119)

Findings such as these were not lost on the National Society for the Study of Education. In the *Thirty-First Yearbook: A Program for Teaching Science* (1932), the need for using technology as a teaching tool was addressed. As part of the proposed program for teaching science, needs associated with the effective instruction of science—curricular, pedagogical, philosophical, and material—were examined. In an extensive chapter devoted to the requirements for science rooms and equipment, a strong case was made by the National Society for the Study of Education (NSSE, 1932) for infusing technology into the science experience.

> Science rooms should provide certain facilities for objectification by means other than the use of concrete materials. This guiding principle calls attention to such items of equipment as the blackboard, bulletin board, display fixtures, charts, and most especially the materials included in the term *visual instruction.* Glass slides, home made slides, film slides, microslides, opaque projectors, the motion picture and the "talkies," all have a valuable place in science teaching. They can provide experiences as real to the pupil as many of the demonstrations and laboratory exercises. Often they surpass the latter in variety, clarity, and pertinence. When properly used, they supplement other experiences, fill in gaps, and tie together ideas that belong together. (p. 294)

These issues connected strongly with the 1930s view of the purposes of science education. Acquiring "functional understanding of the major generalizations of science and the development of associated scientific attitudes" (NSSE, 1932, p. 57) can most successfully attain the purpose of science education, life enrichment. The motion picture, its advantages enumerated above, clearly helped to achieve the desired grasp of science.

Not all the data was gathered with respect to its use in instruction. Freeman (1924) reported on the findings of studies conducted by Hollis and Rolfe. In these studies, it was demonstrated that when comparing instruction by motion picture to that of a teacher performing a demonstration, students seeing demonstrations displayed greater proficiency in duplicating the activity. Rolfe (1924) examined learning in terms of the students' ability to engage in a task when presented comparable information in a motion picture and in a teacher-led demonstration. As summarized previously by Freeman, the findings supported the position that actual involvement in the activity was superior to a virtual experience provided by the motion picture. Thus, evidence was present from the earliest days of the motion picture in education that technology does not represent a panacea for all of education's ills.

Recognizing the engaging nature of the motion picture as an instructional tool, Hunter (1934) offered these comments:

> Most science teachers discovered the value of visual aids long before the movies and talkies began to find a place in the classroom. Free use of charts, models, and lantern slides has for years been considered indicators of good teaching. But today the movie house has developed so great a following that, if we are to compete with the outside attractions, we would seem bound to include the movie and the talkie as definite motivating devices to be regularly used in the science laboratory. (p. 294)

If the words ''television'' and ''computer games'' were substituted for ''movie'' and ''talkie,'' his statement would sound strikingly contemporary.

Beyond the engaging quality of the technology, the utility provided by the motion picture was what led teachers to adopt it as one of their classroom tools. Motion pictures, reported Fern and Robbins (1946), provided aids to understanding ''scientific theories, rules, formulae, and their applications'' (p. 79), consistent with the goals of scientific literacy.

The Second World War provided a significant boost for those who were the pioneers in using the motion picture in education. Significant resources were committed to produce quality training films for the troops and education films supporting the war effort for those who remained at home. The successes enjoyed from the use of these films provided further encouragement for those whose interest fell in the domain of science education.

Shortly after the end of the war, with the publication of the *Forty-Sixth Yearbook,* the motion picture had become, along with chalkboard and textbooks, institutionalized as part of the teacher's repertoire of classroom tools.

The *Forty-Sixth Yearbook,* in 1947, was able to absorb and further transmit much of the enthusiasm for the use of motion picture technology in science education.

> Motion pictures and slidefilms may be used to achieve many of the objectives of science education. Motion pictures and slidefilms are in most cases the next best thing to direct experience when such experience is impossible. In addition, they have two special values. They may depict excellent instruction, thus serving as a model for the effective use of equipment and materials in teaching science, as well as illustrating good method and content. Also, they may, by virtue of their unique characteristics, illustrate scientific phenomena that cannot be seen by the naked eye, such as the solar system, bacteria, and the structure of the atom. The inherent characteristics of the motion picture, including animation, microphotography, time-lapse photography, and slow motion, make possible a realistic understanding of abstract subjects and events of scientific interest. (p. 101)

This constituted strong praise for and confidence in the use of the motion picture in science education. Educators can at times be skeptical consumers of the newest technology or technique. That film so rapidly entered the instructional pantheon spoke well of its perceived virutes.

The Motion Picture in the Classroom

Motion picture technology has been present since the early part of the century. Its use continues, albeit in altered form, to the present. How its presence influenced the science classroom provides the next area of investigation.

The Motion Picture

In the motion picture's formative years in the science classroom, several factors characterized its use. An examination of the science education literature of this era revealed three types of discussions related to the use of the motion picture in the science classroom. Descriptive articles regarding schools that had acquired the technology characterized the early years. This introductory phase led next to articles that examined the successes that characterized instruction using the motion picture. These articles tended to be related to experimental studies involving the use of the technology. Suggestions for informed teaching practice emerged from these articles.

The final cluster of articles represented the institutionalized phase of the technology. At this juncture, preferred practice with the use of the motion picture had been established; journal articles now sought to inform the science educator as to the best choices in terms of software to achieve their educational goals. A review of available films is an excellent example of this phase of the literature's evolution.

The first article on the use of motion pictures in science education in the journal *School Science and Mathematics* was published in 1913. It consisted entirely of a listing of schools that had acquired motion picture equipment for use in science and mathematics education (Levier, 1913). Sadly, no commentary was offered in terms of how the technology was used—simply a listing of schools and the courses which the technology supported. This also underscored one of the initial phases in the infusion of technology into teaching—the acquisition of the hardware itself. The second article on the topic of motion pictures in *School Science and Mathematics* was published later in the same year. Reporting from Germany, motion pictures were said to have ''had a real impetus in German official circles.'' The motion picture was applied to instruction in the ''anatomical, biological, and bacteriological courses'' (*School Science and Mathematics,* 1913, p. 797). As with the previous article, the text offered little for those who wished to investigate the use of the motion picture as a tool in teaching and provoked more questions than answers.

Among the scholars of this early period, the movement towards embracing technology was limited. In a profile of the contents, methods, and resources for an exemplary general science course (Roecker, 1914), no mention was made of the motion picture, let alone lantern slides or other forms of instructional technology.

As was often the case, technology found war to be a catalyst for action. By the end of the First World War, many of the training films were repurposed for the needs of the public at large. Science and mathematics teachers were alerted through the journal *School Science and Mathematics* (1919) as to the availability of numerous films created in support of the conflict which were now available to the public.

The need for appropriate software provided one of the key educational issues in the area of motion picture technology in the science classroom. Finegan (1928) outlined some large-scale commercial efforts to develop and test appropriate software for the science classroom. Researchers at the Eastman Kodak Company produced a series of classroom films with the cooperation of leading educators.

The company's interest in the medium, doubtless influenced by their commercial interest in cameras and film, led to surveys of educators to determine why motion picture technology was so seldom infused into the science curriculum. The findings of the survey (Finegan, 1928) suggested that

> in substance . . . little had been accomplished in the production of suitable films for classroom service . . . [and] there appeared to be little prospect that an organization with sufficient resources would enter upon a program to produce films of this type on an adequate scale. (p. 392)

With the need for this sort of software established, Kodak set out to develop a series of films appropriate for science instruction and test the efficacy of instruction with film and without. At this time, much of the research was exploratory in nature:

> A few experiments in this field have been conducted in this country and in Europe, but the extent and the general scope of such experiments has been wholly inadequate in the results recorded . . . The experiment [was] undertaken . . . in the belief that it would reveal the essential fundamental knowledge for the [goals of this program]. (Finegan, 1928, pp. 391–392)

Apparently the initial results of the study were encouraging (Finegan, 1930). Saettler (1990) reported that eventually 250 educational films were produced as part of the Kodak project. Unfortunately, the deaths of George Eastman and Finegan combined with the Depression to bring to a halt the Eastman Kodak Company's film production projects. Eventually the entire stock of film negatives was donated to the University of Chicago.

Another early examination of the motion picture in science instruction was carried out in a study performed at the University of Chicago. For a large group lecture setting, it was determined that students receiving instruction from the motion picture attained a score of 67%. Those who were exposed to a lecture alone earned a score of 72% (the percentages were assumed to be scores on a post-test related to the content of the lecture and motion picture). Lemon (1922), the researcher, suggested that had there been narration present with the motion picture (this was a silent film), the scores received might have been reversed. In any case, the use of the motion picture as an instructional tool—or as one of a number of instructional tools—was supported by the findings of the study. In terms of efficiency alone, the use of a technician to project the film over a teacher to provide a lecture supported the use of the motion picture in terms of instructional efficiency. Also, from Lemon's perspective, a difference of five percent was not significant in terms of the scores achieved.

Davis (1923) made a direct connection between scientific literacy and technology. He examined in detail the use of motion pictures in science instruction. He summarized his findings to this end:

> In brief, the film can be used in the motivation and enrichment of ideas; it can be used in the promotion of creative thinking; it can arouse curiosity and it can develop the work spirit. The thing of most value in the film is its use tying up different techniques of teaching. The laboratory work, the reading of the textbook, class discussions, questions and problems can all be taught with more interest to teacher and pupil if teaching and learning are supplemented occasionally with good films. (p. 433)

To accomplish the goals he outlined, Davis made a strong case for higher quality films. In particular, he found that most films of the time were simply repackaged for academic use, with too much of the film devoted to entertainment rather than quality instruction. He offered specific suggestions as to engaging means of infusing the motion picture into instruction. At one level, he called for improvement in the quality of educational films; at another level, he made specific pedagogical suggestions that would make the most effective use of the technology in the science classroom.

Addressing the position of the Committee on the Reorganization of Secondary Schools, Davis made clear the uses of the motion picture as a means of accomplishing their broad educational goals. The Committee was a nationally organized group sanctioned by the Department of the Interior and Bureau of Education to analyze the state of American education and identify areas for improvement. The motion picture provided a means of improving the quality of content knowledge gained. It also provided a means, when used interactively (i.e., with the teacher using the motion picture as a tool for making points and illustrating principles, rather than as a substitute for the teacher) of allowing the students to evaluate information and make judgments on the information presented.

The motion picture continued to gain wide acceptance as an educational tool throughout the 1920s. In an editorial titled ‘‘Education or Entertainment?’’ (*School Science and Mathematics,* 1929) the motion picture was included as one of many standard educational tools:

> The school should provide the child with popular science literature, show him educational films and demonstrations, take him to museums, [and] include lectures and travel if possible. . ..(p. 795)

By the early 1930s the use of the film in the classroom had reached the point where it was a standard piece of instructional technology. A 1933 article in *School Science and Mathematics* underscored this point as it detailed the availability of motion pictures suitable for classroom use. This change underscored a shift in the way the motion picture was regarded in the classroom. Rather than focusing on the hardware as early articles had done or the pedagogy as the second generation of articles had addressed, the topic of discussion had moved to what pieces of software were suitable for classroom use. This reflected the overall acceptance of the motion picture as a part of classroom practice, and the need to help teachers make informed choices as to the film to be used in class to take advantage of the tool.

Special types of motion pictures designed to display scientific phenomena were analyzed in detail in Edgerton’s (1935) article on the use of high-speed motion pictures as a classroom tool. Here the intent was the use of the motion picture as a means of enhancing student understanding of scientific processes—in contemporary terms, part of developing scientific literacy. Similarly, special notice (School Science and Mathematics, 1938) was made of a motion picture which

> will give teachers a clearer conception of the teaching aids available in this type of visual instruction. It will also present to students information of definite instructional value. (p. 603)

The motion picture’s value in education had moved beyond the point where the complexity of the hardware was an issue; rather, the motion pictures themselves were seen as ways of developing skills and knowledge related to scientific literacy.

This shift was witnessed by an editorial change in the journal *School Science and Mathematics.* Rather than treating the release of new motion pictures as news articles, a series of reviews were offered of motion pictures suitable for science education, as was done with appropriate textbooks. This shift underscored the comfortable home motion pictures had acquired within the context of science education. The opinions offered were based on the experience of ‘‘science teachers in the [Columbia] Teachers College environment who have had considerable experience in the use of films’’ (Brown, 1939a, p. 197). The reviews addressed the quality of the films in terms of their scientific content, their suitability as teaching aids, and the technical quality of the films. It is interesting to note that the reviews addressed only sound motion pictures; the silent films, common only several years previously, were no longer in production and were rapidly falling out of classroom use.

In a survey of materials and equipment for teaching elementary science (McAtee, 1939), motion pictures provided a significant contribution to the body of materials identified for classroom use. No justification or elaboration as to their need was offered; their use by this time was accepted pedagogy.

The first forty years of the twentieth century showed the birth of this technology in the educational world and its gradual institutionalization. As it became a standard part of the teaching practice, the interest among teachers moved away from the establishment of a pedagogy and training in the use of the projection machinery. Instead it focused on the increased availability of films themselves.

Transition to Mature Practice

By the end of the 1930s, the literature devoted to the use of the motion picture in the classroom had passed through three distinct phases. In the beginning, the literature was focused on the hardware. In the second phase, documentation investigated appropriate pedagogy for the use of the technology. Finally, in the third phase, the technology had achieved a permanent place in the classroom, and the majority of the documentation produced at this point made teachers aware of appropriate software for infusion into the classroom.

The Second World War provided a new impetus for the use of motion pictures in the science classroom. The success experienced by military trainers was not lost on science educators. The efficiency of large-scale and standardized instruction made for an attractive combination. In the field of science education, government-produced films were again promoted for use in science education. The purpose of education had expanded to include a degree of military preparedness (or at least strong empathies) as shared by Stewart (1942; see also *School Science and Mathematics,* 1943). In a description of a series of films designed to ‘‘speed up training of defense workers’’ (Stewart, 1952, p. 705), their application for science education was noted as an additional advantage:

> Many of these films may be used to advantage in science and mathematics classes. Films such as *Steel Rule, Micrometer, . . .* and *Cutting a Spur Gear* not only facilitate the regular work in physics and mathematics but also demonstrate the relationships between these subjects and the work in industry and war production. (pp. 705–706)

Again we see the connection between the purposes of science education at this time and the use of the motion picture to facilitate this goal. Science education, it will be recalled, had recently found its voice in the words of the National Society for the Study of Education (NSSE, 1932):

> This Committee, then, recognizes the aim of science teaching to be contributory to the aim of education; viz., life enrichment. It recognizes the objectives of science teaching to be the functional understanding of the major generalizations of science and the development of associated scientific attitudes. (p. 57)

Several trends marked this post-World War II era. These trends each helped to bring about the goals of scientific literacy and the means by which the motion picture could contribute to its accomplishment.

The first of these trends was represented by the increased availability of film. Numerous film repositories came on line. These, combined with growing recognition of available titles for teaching, helped cement the role of the film within science teaching.

Experiments in the format for films—such as film loops—provided another avenue for the motion picture as a means of developing scientific literacy.

Sharing an opinion piece on the utility of the motion picture as a part of the science classroom, Schreiber (1944) identified the ongoing needs of teachers in terms of infusing motion picture technology into the classroom. Two areas he suggested were lacking in teacher training. One was a lack of awareness of the value of the film in science instruction; the other was teachers who recognized the value of film but were lacking in specific knowledge as to how to use them.

Throughout this era, the motion picture as part of the experience in the classroom was confirmed as a mature classroom technology. That the authors of the *Forty-Sixth Yearbook* recognized the motion picture as a part of a student's standard classroom experience reflected its stable place as a classroom tool.

Improving Pedagogy with Technology: The Film Loop

Further refinements in the pedagogy associated with the motion picture were part of this era. Walter, Brenner, and Kurtz (1957) examined the use of repetition and questioning as a tool to make more effective use of films in the science classroom. Though the significant effects of the study were small, it was determined that in the study's experimental conditions there was a tendency for boys to be more successful than girls through the use of motion pictures as an instructional medium. Significant in terms of this study was the drive to achieve increased use of the motion picture. Films were already an important part of the curriculum, according to the Walter, Brenner, and Kurtz (1957) investigation, so the question becomes what can be done to make their use more effective? How can student learning of science (i.e., scientific literacy) be enhanced? Other studies continued to seek more effective means for the use of the motion picture in the science curriculum.

The curriculum projects of the 1960s brought about an interesting application of the motion picture. Over thirty years after the introduction of the "talkie" as the standard approach for commercial and educational films, the film loop found a place in the science curriculum.

Rather than attempting to duplicate an entire lesson or develop more than one idea in a lengthy film, film loops were single-concept artifacts. The film—a continuous strip—was enclosed in a cartridge for ease of operation. With the need for threading and rewinding the film eliminated and a simple set of controls for the teacher (which included the ability to stop the film loop in action, with minimal damage to the film itself), the film loops provided teachers with a means of better using the moving images to develop concept knowledge. The Physical Science Study Committee (PSSC) physics program is notable for the extensive library of physics film loops developed under its auspices. Such topics such as vector addition and the collapse of the Tacoma Narrows Bridge (notoriously difficult to duplicate in the classroom) were among the many titles available.

By the mid-1970s, the strong bond between the motion picture and science instruction was further cemented by the publication of the American Association for the Advancement of Science's (AAAS) *Science Film Catalog.* It made every attempt to serve as a comprehensive directory to all films that had a worthwhile role in science education. The link between scientific literacy and the value of the motion picture as a teaching tool was made implicit by the author of the catalog's forward: F. James Rutherford. At the time, Rutherford was the chairman of the science education department at New York University and the president of the National Science Teachers Association. (Within the decade, he would serve as one of the primary authors of *Science for all Americans* (AAAS, 1989), one of the preeminent statements of scientific literacy of the current era.)

> In his catalog introduction, Rutherford (AAAS, 1975) made the following statement: Now thanks to the AAAS . . . we have in a single source a film catalog that is comprehensive, that uses standard library referencing, and that is usefully categorized. I am confident that more thoughtful use of science films will result; if so, our students as well as ourselves will have been well served. (p. vii)

Further remarks connecting the film with the goals of scientific literacy were found in the preface.

> Helping this public [defined as the school and college student population and their teachers] to understand the sciences and the scientists as well as the social and political ramifications of science and technology is an important function of the communications media. Through this *Catalog* we hope to increase the use of science films and, consequently, to increase the public's understanding of science. (AAAS, 1975, p. ix)

The connection between the use of this technology and the goals of scientific literacy was made abundantly clear in the previous set of remarks. The goal of producing a scientifically literate citizen was stated in the remarks of the preface.

Another important transition was made clear by the scope of the *Science Film Catalog,* especially when contrasted with early works such as the Gages' (1914) *Optical Projection.* The focus was no longer on the hardware; rather, the software that supported the instructional goals became the primary issue for science teachers. That few volumes similar to *Optical Projection* were produced in the move to videotape spoke volumes about the simplicity of the newer technology and of the comfortable status the motion picture (and it successor the videotape) had assumed in the science classroom.

Transition to Video

By the 1980s, the motion picture, in the film format, was a mature and entrenched part of the culture of the science classroom. Changes since the 1980s have related to the format of the technology, which have contributed to its current role within the science classroom. The notable movement has been away from the motion picture as film and into new technological formats: videotape and videodisc. These newer versions of the older film technology also offered some advances in terms of classroom application. The videotape offered lower costs and greater flexibility of use, especially with teacher and/or student created artifacts. The videodisc offered high-quality, rapid access to images and the potential to interface the software with the computer.

Videotape

Videotape provided a low-cost alternative to motion picture film. It also had a built-in flexibility which motion pictures did not possess to the same degree: a classroom teacher could create his or her own videotapes or simply record a television broadcast for later use in the classroom.

Videotape was available by the 1950s. With the increased availability of video players, commercial videotapes, and video cameras, the motion picture entered an entirely new phase in classroom practice.

By the end of the 1970s, the motion picture—in the film format—had begun to be replaced by a new format: the videotape. This change allowed several new options in the classroom experience with technology. The first gave the teacher greater power to capture images personally and use them in the classroom. The second offered the chance to capture broadcast programs and infuse them into their curriculum. Finally, the relatively lower cost of the hardware and software made the videotape more available for all concerned.

Serving as a link between science teaching practice and using technology in the classroom, Reynolds and Barba's text *Technology for the Teaching and Learning of Science* (1997) provided a guide for those who wished to examine current science classroom practice with the use of technology.

Reynolds and Barba's (1997) suggested uses of videotape moved beyond simply showing videotapes to students. They saw technology as a means of enhancing science process skills. To cite one example related to videotape, videotape and the videotape recorder were suggested as means of making observations and collecting data. The authors urged for a number of reasons the use of video in the science classroom.

> Video-based instructional activities enhance science teaching and learning in that they (a) allow students to observe events in the natural world that are normally too quick, too slow, or otherwise too difficult to observe, (b) supply visual representations of science phenomenon, (c) permit students to reflect upon their observations, (d) provide verification of students observations, and (e) encourage students to hypothesize. (Reynolds and Barba, 1997, p. 71)

Moving from the points identified above, the use of video in the classroom developed science process skills in these ways:

> The very act of using a video camera to record observation or preserve an event results in your focusing attention on the subject. This focused attention occurs when you are deciding what to videotape, when carrying out the camera work, and finally, when viewing the result. (Reynolds and Barba, 1997, p. 71)

The video camera offered the means of developing the observation process skill:

> Recording an event on tape allows repeated observations. By viewing a videotape, not once, but several times, students can confirm the details of an observation and usually discover details that [had] previously not registered with them. (Reynolds and Barba, 1997, p. 71)

The level of student engagement in the activity—a worthwhile goal in the context of hands-on/minds-on science instruction—can be enhanced by the use of videotaping.

> Videotaping gives students control over time: action can be slowed or accelerated through slow motion or time lapse photography techniques, allowing students to study specific details of changes that have occurred, or to dramatize the change process. (Reynolds and Barba, 1996, p. 71)

The applications of videotape in science education remained similar, in many ways, to the original suggestions for the use of the motion picture in science education. The focus on observation, on bringing experiences to students, and observing what was impossible to duplicate in the classroom were all reasons offered for the use of the motion picture as a classroom tool. An advantge of videotape over the film, however, was the ease of producing and capturing one's own set of images. Production costs were essentially zero; once the images had been recorded, they were ready for playback.

The simple nature and adaptability of the videotape provided another area of suggested use by science teachers.

> The use of video cameras, or videotapes is adaptable to a variety of instructional approaches and settings—individuals, small groups, and large groups; prescriptive, guided, and independent use; for demonstration, exploration, and experimental investigating; in the classroom, outdoors, on field trips, and for home assignments. (Reynolds and Barba, 1996, p. 71)

A number of creative suggestions for classroom practice were identified. An application such as using a video camera to create a close-up image of a chemical reaction, both to allow students to see it better and to make a permanent record of the event, was typical (Reynolds and Barba, 1996).

Moving from methods text to the classroom, Michael and Brinkhorst (1991) shared a number of their classroom experiences using a video camera in an article in *The Science Teacher.* They made use of the camera's data collection strengths to structure a number of student activities to promote and clarify student understanding of physical phenomena. In particular, using the ability of the video images fixed rate of recording allowed measurements that were previously qualitative to become quantitative.

One example of using the ability to record events on videotape was related by Park and Lamb (1992). In one sense, their use of video brought the use of the motion picture ''full circle'' with the earlier applications in that they were using selected vignettes from commercially released motion pictures. Their application of the video images was to have students analyze the situation depicted on the videotape from a point of view informed by the laws of physics. One particularly amusing episode involved students using scenes from the movie ''Superman II'' to estimate the speed of Superman as he conducted a rescue of a falling child.

The Videodisc

The videodisc entered the science classroom during the 1980s. In its simplest form, it was used in much the same fashion as a motion picture, by simply showing a motion picture or an educational program all the way through.

The technology, however, allowed for a number of advances over both film and videotape. A vast quantity of information—over 55,000 individual images—could be stored on a single disk; the images could represent either single discrete frames or one of a series of frames in a moving image.

Related to the nature of the storage, access to the images was virtually instantaneous. The time spent waiting for suitable footage to be advanced on the reel or film or the videocassette was eliminated. This point was emphasized by Scaife and Wellington (1993):

> A laser vision disc [videodisc in US terminology] for example . . . can store up to 55,000 still pictures or 37 minutes of video footage on one side. A disc is far more than a video cassette in this context, largely because of its direct and fast access using digital location of data which can be managed by the computer. (p. 70)

The videodisc was typically used in two different approaches. The use termed ''Level I'' put the instructor in direct control of the sequence of video images desired. The ''Level II'' use of the videodisc made use of a navigation program built into the videodisc itself. This program helped to control the sequence of the video images. Ultimately, this form of the technology was used only occasionally, as the programming on the videodisc tended to be videoplayer-specific. By the late 1980s, the nature of the technology also made it ideally suited for interactive multimedia applications with a computer interface. In this format, a computer selected the sequence of images by a predetermined program or in response to the apparent needs of the learner. This computer-controlled use of the videodisc was described as ''Level III.''

The use of the videodisc as a tool in science teaching took off rapidly during the late 1980s. For use in the science classroom, Barron, *et al.* (1994) identified specific advantages associated with the use of videodisc. Movies and documentaries provided one application of the videodisc, an application of the technology similar to its previous incarnation as film and videotape. Applications more closely associated with the videodisc itself included instructional games, tutorials, visual databases, multimedia libraries, demonstrations, video report makers, and inquiry activities. Their study suggested that the fundamental structure of the videodisc technology lent itself to applications in teaching and learning which would benefit from the flexible and interactive nature of the software.

Other studies regarding the effective use of this technology appeared during the late 1980s and early 1990s. Similar to studies comparing the effectiveness of standard classroom instruction with that of the motion picture seven decades before, initial studies examined the use of the videodisc as a classroom tool.

In one particular application of the technology, Muthukrishna, Carnine, Grossen, and Miller (1993) examined the use of the videodisc as a means of addressing students' alternative frameworks. (An ''alternative framework'' can be considered a student's misconception of a scientific principle. Typically these children display an understanding inconsistent with the accepted understanding of the phenomenon. A typical misconception is that the seasons are due to the sun being closer to the earth in the summertime, rather due to the tilt of the earth's axis.) The videodisc, when used as part of a well-designed science curriculum, was found to change 92% of the existing alternative frameworks held by students. The flexible nature of the technology allowed the instructor to offer lessons that:

> controlled critical curriculum design variables in presenting concepts . . . and provided immediate guided application [which] seemed to more efficiently eliminate alternative frameworks than those who used instruction time to focus on alternative frameworks exclusively. (Muthukrishna, *et al.,* p. 244)

When compared with a control group that did not make use of the videodisc as an instructional tool, the experimental group outperformed the control group. The videodisc, as part of a well-organized curriculum, helped students to address and conquer existing misconceptions.

Findings by Hasselbring, Sherwood, Bransford, Fleenor, Griffith, and Goin (1987–88) would seem to confirm this. In a study examining the Level I use of a videodisc as an instructional tool, the data gathered led to the conclusion that the

> gains found in the study were related to the instructional nature of the . . . program and not to the novelty of the videodisc medium. Finally, it was found that even though the program had a positive effect on student achievement, the effectiveness of [the videodisc], like other instructional programs, is somewhat dependent upon the commitment and quality of the teacher using the software. (p. 151)

Other findings, such as those by Hoffmeister, Englemann, and Carnine (1989) further confirmed that the videodisc could be an effective classroom tool. When used appropriately in the classroom, Hoffmeister and his colleagues found that the videodisc helped in the following areas: in countering the fragmentation in the curriculum, by promoting instructional clarity, by the accurate use of terminology, by countering instructional vagueness (on the part of the classroom teacher), and by the careful sequencing of instruction.

Based on those principles of successful instruction with the videodisc, several programs of note were used by the early 1990s in classrooms at the elementary and secondary levels.

Full Option Science System. The Full Option Science System, universally known by its acronym (FOSS), provided for the elementary teacher of the late 1980s and early 1990s a comprehensive classroom tool for science instruction. In addition to a set of hands-on science manipulatives, a set of ten videodiscs provided over five hours of information and experiences for the teacher to use as a part of classroom instruction. An exhaustive series of manuals provided instructional suggestions, as well as a comprehensively indexed (by bar code) set of videodisc images. As discussed in Chapter 4, complementary computer software allowed for Level III use of the videodiscs by either students or teachers.

Profiled in the staff development program *Capturing Excellence* (Thompson, 1997), an elementary teacher made these remarks on her use of the "Science Essentials" videodisc as an instructional tool in her science classes:

> I decided at this point in the lesson to use the laserdisc [previously a common name for the videodisc] to bring in a real-life example for the children. I could have given them examples, or talked about examples, [such as] at the airport, or downtown Chicago to try to get that picture into their mind. But the laserdisc gives me accessible, easy-to-use ways of bringing real-life situations into the classroom for the kids to take a look at. So the picture in their mind is there as they begin to work with the materials in the class. I had used the teacher's guide ahead of time to find this particular segment. It was readily available for me to use with the barcode. I used a light pen, then scanned it across the barcode, then I could access the information easily (audio track 4, frames 05857–07387).

She provided further elaboration as to why the videodisc was her medium of choice for certain activities.

> I like laserdisc technology because I can control which brief segments to use and they can both enhance and clarify my lessons. I can efficiently access brief segments to clarify and enhance my lessons. There are times during the lesson when I like to use the remote and freeze frame. This allows me to go into greater detail. (audio track 4, frames 15857–16540)

Windows on Science. Optical Data Corporation's videodisc products such as *Encyclopedia of Animals* (1987) provided another example of a comprehensive videodisc designed for elementary classroom instruction. Related to the point developed previously, that the videodisc is an effective tool only within the context of effective pedagogy and curriculum, the *Encyclopedia of Animals* package provided a user-friendly interface (similar to that of the FOSS program). A set of annotated barcodes were supplied to make selection of appropriate footage a simple matter. In terms of the curriculum, the series was developed as a "video textbook" which was designed to provide a highly structured series of images for students. The consistent theme of "fitness," in a Darwinian sense, provided the overarching structure for the instruction (Optical Data Corporation, 1987). For an existing biology curriculum, the wide variety of video clips were designed to help students gain an understanding of the concepts covered within the school's curriculum. The ease of access and complete annotations made it a simple matter for teachers to infuse videodisc technology into science instruction.

The series benefited from a number of investigations into the utility of the approach. A series of studies conducted through the University of California (Irvine) found the materials to be helpful in several different areas (University of California-Irvine, Department of Education, 1993):

> The studies all used reliable assessment procedures to examine the implementation and outcomes associated with these bilingual science videodisc programs. Although they were conducted with varying groups of student populations and in different sites, the studies demonstrated striking similarities. Large positive effects associated with the use of the program were consistently found in student attitudes. These included substantial gains in the attitudes towards science of male and female students. Positive effects were demonstrated on students' knowledge in science based upon science achievement test scores. (p. 1)

Based on these findings and others (Anthony, 1992; Denham, 1991; and McWhirter, 1991), empirical evidence supporting the use of the *Windows on Science* programs has helped to move this technology into the classroom.

While the program was conceptually sound and showed that it could be an effective component of a science program, some resistance to the use of *Windows on Science* appeared. The common point of contention was that the series was perhaps *too* structured. While in some senses this was an advantage—inexperienced teachers or teachers with little content knowledge were found to be well served by the program (Denham, 1991)—others found the structure and heavily scripted lessons to be frustrating. The lesson to be gained from these insights was that technology should not merely automate instruction, it should emancipate it as well.

National Geographic Video. Not all videodiscs were designed as components of a larger science curriculum. The National Geographic Society's *Born of Fire* (1983) was one such example. This approach was similar to the uses of motion picture in the classroom of the 1930s. Rather than providing the entire act of instruction, the video provided a single, coherent set of images to support classroom instruction needs. As the videodisc medium was rather expensive, the single-use approach proved to be fairly uncommon, but it provided an excellent compendium of visual images for students to examine.

Science Sleuths. Midway between a single-topic videodisc and an entire series of videos, the *Science Sleuths* provided a viable alternative. The expense of the videodisc was diffused in that several episodes were included, rather than a single program as in the National Geographic approach. Focusing on the process skills of science more than a single area of content, the *Science Sleuths* videodisc was comprised of 13 separate episodes. Consistent with 1990s views on scientific literacy, the focus was on problem-solving skills and on student understanding of the "use of scientific knowledge, ideas, and inquiry processes" (National Research Council, 1996, p. 52) and "providing opportunities for scientific discussion and debate among students" (NRC, 1996, p. 52).

Interactive Frog Dissection. At the secondary level, the dissection of animal specimens has long been standard practice in biology classes. To diffuse opposition surrounding the use of live specimens–ethical and financial (Strauss and Kinzie, 1994b)–an alternative was created in the form of an interactive videodisc on the topic of frog dissection. One advantage cited by a biology teacher, making a comparison between the videodisc and previous motion picture representations of the dissection experience, was:

> interactive video . . . can provide high quality video . . . with greater interactive capabilities than the film-based methods previously used in anatomy instruction. (Strauss and Kinzie, 1994b, pp. 398–399)

Investigation of the use of the videodisc as compared to an actual dissection experience led to several conclusions. Related to the quality of the learning, Strauss and Kinzie (1994a) found that data supported the position that videodisc-based instruction was as effective as an actual animal dissection in terms of the content knowledge gained. Interestingly, in terms of attitudes toward the value of dissection, those students who participated in dissection, over time, reported that their regard for the value of the dissection increased; those who participated in the videodisc-based dissection reported that their perception of the value for an actual dissection decreased with the passage of time. The authors suggested that this effect was likely due to the "subjects' preferences for selecting the same instructional method that they used in this study in the future'' (Straus and Kinzie, 1994b, p. 401).

In the physical sciences, a number of videodiscs were available as well by the middle 1980s. Some of the products were simply classic education films produced in a new format; others were new productions designed to make use of the flexibility of the new technology (Kirkpatrick and Kirkpatrick, 1985, p. 401).

The Puzzle of the Tacoma Narrows Bridge Collapse. A videodisc which for many in the physical sciences defined the advantages of the technology for the classroom was *The Puzzle of the Tacoma Narrows Bridge Collapse.* Produced in the early 1980s, it was the first videodisc created for use by physics teachers. Combining an historical examination of the bridge's construction and its fascinating collapse with an investigation into the characteristics of waves and structures, the program also offered the student three paths by which to view the information, depending on the level of sophistication desired (Kirkpatrick and Kirkpatrick, 1985). Through a series of experiments carried out on models of bridges, the images engaged the student at a high level, focusing on the ability to evaluate data and draw conclusions from the findings.

Links to Scientific Literacy

When observed through the lens of social psychology, the tendency to engage in certain behaviors is related to expectations for success in that behavior and the perceived value of engaging in that behavior.

The use of a technology such as the motion picture as a component in a science course relied on several issues. The teacher must have recognized the utility associated with the use of the motion picture. The teacher must have had some expectation of success related to the use of the technology. The teacher must have had evidence that the cost of learning to use the technology is worthwhile and the teacher's level of interest must have been sufficiently high to make the use of the technology worthwhile (Eccles [Parsons], 1983).

The issue of the perceived value—the utility of the technology—informed the overriding reason for infusing the motion picture into science instruction. The use of technology provided the teacher with an enhanced means of achieving scientific literacy. The sophisticated tool represented by the motion picture offered an engaging and effective means of helping to achieve the goals of scientific literacy.

Early in the century, with the Nature Study approach a strong influence in science education, it was easy to see how a motion picture could be used to advocate the values inherent in the Nature Study approach. A notice in *School Science and Mathematics* in 1931 implied much about the progress of developing educational films. A motion picture profiled in an article was lauded for the perspective it could bring to the classroom. The topic of the film was the use nature could be for man. The title of the article—''New US Film Shows Ways In Which Forests Serve Man'' (p. 394)—implied more about the scholarly thought with regard to science education at the time than the actual content of the film. The motion picture reflected the views associated with the Nature Study movement—and with it a tendency to see the world only in terms of how it supported human needs—and empathy for the agricultural lifestyle promoted by Nature Study advocates. Brodshaug and Strayer (1932), reflecting on the suitability of the motion picture for teaching topics associated with the Nature Study curriculum, found further support for the purposes of the Nature Study movement through the use of the motion picture.

> In the past, the excursion has been looked upon as the prime device in nature study. The inadequacy and impracticality of excursions are among the chief reasons that elementary science has, in many instances, failed to attain the objectives set up for it . . .
>
> It is our belief that sound pictures will stimulate the imagination, which may lead to a desire to investigate in greater detail the ideas that have been brought out by the picture. . . . (p. 361)

In the early part of this century, in the text of the *Thirty-First Yearbook,* the purpose of science education was defined by the National Society for the Study of Education

> to be contributory to the aim of education; viz., life enrichment. It recognizes the objectives of science teaching to be the functional understanding of the major generalizations of science and the development of associated scientific attitudes. (NSSE, 1932, p. 57)

The use of the motion picture reflected the position stated in the *Thirty-First Yearbook.* The motion pictures of this era were primarily vehicles for bringing content knowledge to students, helping to bring the information needed for students to develop their understanding of the "major generalizations," noted Hunter (1934),

> The motion picture also has other definite values than that of motivation. It takes the place of the field excursion and the visit to the manufacturing plant. For the purposes of explaining and summing up the applications of science in manufacturing, mining, engineering projects, fisheries, and the like, it is unexcelled, provided the legends are made for the age level at which the film is used. (p. 301)

Statements paralleling those of Hunter were made by Rulon (1933) in his book *The Sound Motion Picture in Science Teaching.* In this book, he profiled a number of investigations into the use of the motion picture as a tool in science teaching. In the appendix, the instrument used to gauge student learning displayed an educationally simplistic point of view; true/false and multiple choice questions related to the content knowledge of the films used in the study form the instrument by which student learning was measured. Though the questions were knowledge-level questions and asked the students to offer nothing deeper, the findings supported the use of the motion picture as a tool in science teaching.

The *Forty-Sixth Yearbook* was quite direct in its advocacy of technology. "Motion pictures and slidefilms may be used to achieve many of the objectives of science education" (NSSE, 1947, p. 57). The document identified issues related to both suitable instruction and curriculum concerns. An extensive range of instructional possibilities were offered by the NSSE (1947).

> In certain situations the motion picture . . . may be developed as a self-contained unit, embodying motivation, concept teaching, review and summarization, activities, and follow up work. (p. 102)

The limitations of the technology were recognized as well. The inflexible nature of the motion picture was, in particular, called to task.

> . . . the motion picture has some very definite limitations as a visual aid. It is inflexible in that the teacher cannot alter the time allotted to any one scene in the motion picture. In contrast, the film strip is highly flexible in that the teacher can spend one minute or ten on each frame, according to her conception of relative importance. In addition, she can, if she wishes, turn back the strip to any frame to which she desires to make additional reference. Also, the slide film has obvious possibilities as a teaching medium, since it allows for active participation and discussion on the part of both children and teachers, whereas the motion picture limits such active participation since the presentation of the subject matter is fixed and beyond control of the teacher. (NSSE, 1947, p. 103)

Forty years later, advances in technology rendered moot these critiques of the motion picture. But at the time these were genuine concerns related to how to best use the technology in the classroom.

Instructional issues related to the use of the motion picture were not addressed in the *Fifty-Ninth Yearbook* (NSSE, 1960). By the late 1950s, the needs of curriculum and instruction had apparently resolved themselves in terms of the use of motion picture technology. Too, the technology had remained fundamentally the same for the thirteen years between the publication of the *Forty-Sixth* and *Fifty-Ninth* yearbooks. What was present was a statement outlining conditions necessary within schools such that teachers could make optimum use of the technology. Indeed, all manner of audiovisual aids were addressed in a single paragraph.

> Rooms should be equipped with a projection screen placed in a permanent location. To simplify "plugging in," the speaker-cable conduit should extend the length of the room. Darkening facilities, chalkboards, tackboards, display cases (one visible from the corridor) are minimum requirements. (NSSE, 1960, p. 237)

By the 1960s, with the dominant view of science education encapsulated in the term "scientific literacy," films were no longer considered so much an agent of educational efficiency. Rather, the use of the motion picture was to assist in the development of thinking skills, process skills, and problem-solving skills.

The impetus for using motion pictures was still to teach science "better." The definitions that informed "better" teaching had evolved from a focus on content knowledge–which showing a film as a substitute for a teacher's lecture accomplished admirably. By the 1960s, with the use of single-concept film loops, and the 1990s, with the videodisc and videotape allowing the teacher the ability to craft his or her own set of video images, the images were used to develop thinking skills.

As an example of the thinking skills—referred to as "Habits of Mind" in *Benchmarks for Science Literacy*—the development of more sophisticated observation and critical response skills were essential components directed toward the achievement of scientific literacy. Using the skills of observation to make use of a video image and then evaluating the quality of the information contained in the video represent some examples of how this medium was used by the 1990s. Using the information presented in a film or videotape, developing inferences, and drawing conclusions with the information presented represented a more sophisticated use of the technology than simply relying on it for content information. And the increased sophistication was consistent with the evolving requirements of what constituted scientific literacy.

Summary

This paper served to describe classroom practices associated with the motion picture as a means of achieving scientific literacy. As the twentieth century progressed, several trends related to the use of motion picture technology in science education became evident. Three categories suggested themselves from classroom practices examined:

1. Development of interest and focus on the hardware.
2. Development of appropriate pedagogy, and
3. Dissemination of software as the use of technology enters a mature state.

Pioneers in the use of the technology provided the first step in this sequence. These individuals were the first to make application of the new technology in a classroom situation. The focus on the hardware—the machinery used to project the images—represented a continuation of the first phase in the literature related to the use of technology. It typically provided insights for those in the second wave of technology infusion.

Developing appropriate pedagogy was a process that continued throughout the presence of motion pictures in the classroom, from their earliest incarnation as silent movies to their more recent expression through videodisc technology.

As the technology matured, research articles and investigations examining pedagogy related to use of the technology declined in frequency. By this point, the motion picture had ''arrived'' as a standard part of the teacher's repertoire. Interest at this point among classroom teachers was more in terms of the type of software available for their classroom practice. The reviews offered by Brown (1939a, 1939b, 1939c, 1939d, 1939e, and 1939f) in *School Science and Mathematics* provided evidence of this focus.

This process repeated itself in a similar fashion with the adoption of first the videotape and then the videodisc as standard means of classroom instruction. Early ''pioneers'' clarified the use of the technology in the classroom. Their initial work with the videodisc informed the standard practice of the day.

A trend of significance related to the use of the motion picture reflected changes in the pedagogy and the development of ''thinking skills'' described in the recent curriculum standards for science education. Early in the century, the motion picture was compared to the human teacher to determine which was more effective. In experimental studies examined from the 1920s, either a human or a machine offered the entire lesson. By the 1960s the issue had moved away from the use of the technology to do all of the instruction; rather, the technology and the teacher worked as partners, with the teacher selecting appropriate images for a more selective use. The days of the motion picture providing the entirety of the instruction had passed. Park and Lamb's (1992) use of motion picture images to develop thinking skills in physics may not have met Thomas Edison's goal of ''100 percent efficiency,'' but it did reflect a deeper thinking process and a classroom of engaged students, an outcome of perhaps greater significance.

The motion picture remains a key classroom tool for science teachers. Videotape and videodisc—the current manifestation of motion pictures—are in virtually every classroom.

REFERENCES

American Association for the Advancement of Science. (1975). *Science Film Catalog,* American Association for the Advancement of Science and New York, Washington, DC.

American Association for the Advancement of Science. (1989). *Science for all Americans,* Oxford, New York.

American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy,* Oxford, New York.

Anthony, A. D. (1992). The Meyersville School's Utilization of Windows on Science. Unpublished Ed.S. thesis, Eastern Illinois University, Charleston.

Averill, G. E. (1995, March). Build your own seismograph. *The Science Teacher* 62(3): 48–52.

Barron, A., Breit, F., Bouleware, Z., Bullock, J., Bethel, E., Hoffman, D., Kritch, K., and Thompson, T. (1994). *Videodiscs in education: Overview, evaluation, activities,* University of South Florida Center for Excellence in Mathematics, Science, Computers and Technology, Tampa, FL: (ERIC Document Reproduction Service, No. ED 384 335).

Broadshaug, M., and Strayer, J. F. (1932, October). Sound pictures in elementary science. *Science Education* 360–367.

Brown, E. H. (1939a). Motion picture reviews. *School Science and Mathematics* 39: 197–199.

Brown, E. H. (1939b). Motion picture reviews. *School Science and Mathematics* 39: 297.

Brown, E. H. (1939c). Motion picture reviews. *School Science and Mathematics* 39: 396.

Brown, E. H. (1939d). Motion picture reviews. *School Science and Mathematics* 39: 493.

Brown, E. H. (1939e). Motion picture reviews. *School Science and Mathematics* 39: 595.
Brown, E. H. (1939f). Motion picture reviews. *School Science and Mathematics* 39: 894.
Cuban, L. (1986). *Teachers and Machines: The Classroom Use of Technology Since 1920,* Teachers College Press, New York, p. 9.
Davis, I. C. (1923). The use of motion pictures in teaching general science. *School Science and Mathematics* 23(5): 425–433.
Den ham, —. (1991).
Eccles (Parsons), J. (1983). Expectancies, values, and academic behaviors. In Spence, J. T., (Ed.), *Achievement and Achievement Motives: Psychological and Sociological Approaches,* Freeman, San Francisco: pp. 75–146.
Edgerton, H. E. (1935). High-speed motion pictures, *School Science and Mathematics,* 35: 646.
Fern, —and Robbins, — (1946).—p. 79.
Finegan, T. E. (1928). An experiment in the Development of classroom films. *General Science Quarterly* 391–406.
Finegan, T. E. (1930, January). The results of the experiment with Eastman's classroom films. *Nature and Science Education Review* 56–63.
Freeman, F. N. (1924). *Visual Education,* University of Chicago, Chicago.
Gage, S. H., and Gage, H. P. (1914). *Optical Projection,* Comstock, Ithaca, NY, p. iii.
Hasselbring, T., Sherwood, R., Bransford, J., Fleenor, K., Griffith, D., and Goin, L. (1987–88). An evaluation of a level-one instructional videodisc program. *Journal of Educational Technology Systems* 16(2): 151–169.
Hoffmeister, A. M., Engelmann, S., and Carnine, D. (1989). Developing and validating science education videodiscs. *Journal of Research in Science Teaching* 26(8): 665–677.
Hunter, G. W. (1934). *Science Teaching at Junior and Senior High Levels,* American, New York, p. 294.
Kirkpatrick, L. D., and Kirkpatrick, D. S. (1985). The physics teacher and the videodisc. *The Physics Teacher* 62(6): 401–418.
Lemon, H. B. (1922). The use of motion pictures in physics teaching. *School Science and Mathematics* 22(3): 254–255.
Levenson, W. B., and Stasheff, E. (1952). *Teaching Through Radio and Television,* Rinehart, New York.
Levier, S. L. (1913). Motion pictures in schools. *School Science and Mathematics* 13(7): 623–624.
Mast, G. (1981). *A Short History of the Movies,* University of Chicago, Chicago.
McAtee, V. (1939). Materials and equipment for the teaching of elementary science. *School Science and Mathematics* 39: 15–28.
McWhirter, M. (1991). *The Effect of Level One Videodisc Technology on Sixth-Grade Student Achievement in Science,* Tomball Independent School District, Tomball, TX.
Michael, V. and Brinkhorst, B. (1991). Focus on video labs. *The Science Teacher* 58(6): 41–44.
Muthukrishna, N., Carnine, D., Grossen, B., and Miller, S. (1993). Children's alternative frameworks: Should they be directly addressed in science instruction. *Journal of Research in Science Teaching* 30(3): 233–248.
National Research Council. (1996). *National Science Education Standards,* National Academy Press, Washington, DC, p. 52.
National Society for the Study of Education. (1932). *Thirty-First Yearbook, Part I: A Program for Teaching Science,* University of Chicago Press, Chicago, pp. 57–294.
National Society for the Study of Education. (1947). *Forty-Sixth Yearbook: Science Education in American Schools,* University of Chicago Press, Chicago, p. 101.
National Society for the Study of Education. (1960). *Fifty-Ninth Yearbook: Rethinking Science Education,* University of Chicago Press, Chicago, p. 237.
Optical Data Corporation. (1987). *Encyclopedia of Animals Lesson Guide,* Optical Data Corporation, Warren, New Jersey.
Park, J. C., and Lamb, H. L. (1992). Video vignettes: A look at physics in the movies. *School Science and Mathematics* 92(5): pp. 257–262.
Reynolds, K. E., and Barba, R. H. (1996). *Technology for the Teaching and Learning of Science,* Allyn and Bacon, Boston, p. 71.
Richardson, J. S. (1957). *Science Teaching in Secondary Schools,* Prentice-Hall, Englewood Cliffs. NJ.
Roecker, W. F. (1914). An elementary course in general science: Content and method. *School Science and Mathematics* 14(9): 755–769.
Rolfe, E. C. (1924). A comparison of the effectiveness of a motion picture film and of demonstration in instruction in high school physics. In Freeman, F. N. (Ed.), *Visual Education,* University of Chicago, Chicago, pp. 335–338.
Rulon, P. J. (1933). *The Sound Motion Picture in Science Teaching,* Harvard University Press, Cambridge.
Saettler, P. (1990). *The Evolution of American Educational Technology,* Libraries Unlimited, Englewood, Colorado, p. 96.
Scaife, J., and Wellington, J. (1993). *Information Technology in Science and Technology Education,* Open University Press, Philadelphia, p. 70.
Schlenker, R. M., and Yoshida, S. J. (1991, February). A clever lever endeavor. *The Science Teacher* 58(2): 36–39.
School Science and Mathematics. (1913). Moving Pictures in German Education. *School Science and Mathematics* 13(9): 797.
School Science and Mathematics. (1919). Motion pictures for you. *School Science and Mathematics* 19(6): 568.
School Science and Mathematics. (1929). Education or entertainment? *School Science and Mathematics* 29(8): 795–796.
School Science and Mathematics. (1931). New US film shows ways in which forests serve man. *School Science and Mathematics* 31(4): 394.
School Science and Mathematics. (1933). Motion picture films. *School Science and Mathematics* 33(2): 133.
School Science and Mathematics. (1938). Motion picture takes man apart. *School Science and Mathematics* 38: 603.
School Science and Mathematics. (1943). Movies become wartime engineering tool. *School Science and Mathematics* 43: 711.
Schreiber, R. E. (1944). The use of films as a teaching aid. *School Science and Mathematics* 44: 59–66.
Stewart, L. E. (1942). Motion pictures for defense training. *School Science and Mathematics* 42: 705–706.
Strauss, R. T., and Kinzie, M. B. (1994a). Hi-tech alternatives to dissection. *The American Biology Teacher* 53(3): 154–158.
Strauss, R. T. and Kinzie, M. B. (1994b). Student achievement and attitudes in a pilot study comparing an interactive videodisc simulation to conventional dissection. *The American Biology Teacher* 56(7): 398–402.
Thompson, T. E. (1997). *Capturing Excellence: Elementary School Science Instruction—Infusing Technology II,* Illinois State Board of Education, Springfield, IL.
Thorp, M. F. (1939). *America at the Movies,* CT, Yale University Press, New Haven, pp. 19–20.
University of California, Irvine, Department of Education. (1993, May 7). Analysis of Findings: The Effectiveness of Optical Data Corporation's Science Videodisc Series, University of California, Department of Education, Irvine, CA.
Walter, J. S., Brenner, H. R., and Kurtz, A. K. (1957). The effects of inserted questions and statements on film learning. *School Science and Mathematics* 57: 541–553.
Wood, B. D., and Freeman, F. N. (1931). Motion pictures in the class room. In Curtis, F. D. (Ed.), *Second Digest of Investigations in the Teaching of Science,* P. Blakiston's Son, Philadelphia, pp. 118–119.