Movies in chemistry education

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Abstract

This article reviews numerous studies on chemistry movies. Movies, or moving pictures, are important elements of multimedia and signify a privileged or motivating means of presenting knowledge. Studies on chemistry movies show that the first movie productions in this field were devoted to university lectures or documentaries. Shorter movies were limited to a single experiment, to be used in the classroom. Movies for preparing for laboratory work and examinations appeared later. The article offers useful information about the ways in which chemistry movies have been used in the last half-century and the benefits such movies provide students in the school environment. The article also offers recommendations on perspectives concerning the training of teachers who are involved in using chemistry movies as a method of instruction in their classes.

Keywords: Chemistry Movies, Chemistry Education

Introduction

Since 1957, movies have been used in many ways in chemistry education. The use of chemistry movies in the school environment provides the student with countless benefits. Training teachers is of the greatest importance in making effective and productive use of movies in educational environments. With the use of movies, styles of learning change, and teachers are required to adapt to such changes in classroom education. Equally as important to having chemistry movies become effective and productive in the educational environment through the choice of a suitable teaching method and strategy is their production. The production process includes the content of the movie, the chemistry knowledge offered, a suitable and effective choice of images and the length of the movie. With today's changing perspective on education, the production of chemistry movies is a process in which experts in different areas such as chemists, chemistry educators and specialists in computer technologies work together. Thanks to advanced technologies, chemistry movies produced today are now recorded on CD's and made available to students as part of their educational curriculum.

The present study is important in that it sets forth the different ways that chemistry movies have been used in the last fifty years. The research also presents information that will be useful to readers in understanding what benefits students can derive from the use of movies in learning environments and in comprehending why teachers should use these movies in their teaching. Another aspect of the study is that it serves to be helpful in the absence in the literature of any compilation of studies on the use of movies in chemistry education. The present study thus seeks to fill this gap in the literature and endeavors to make a contribution to future studies on the subject.

Chemistry Movies from 1957 to the Present

The works cited in this section are more concerned with the benefits of the described innovation rather than with related research. The section has been presented according to the form in which the movies have been used and in chronological order.

Filmed Instruction

The first tracks of chemistry movies with a didactic intention consisted of a series of courses filmed in 1957 to be broadcast on a closed-circuit television network at a university in the US state of Oregon (Slabaugh & Hatch, 1958). The same year, surveys were conducted to evaluate student attitudes about these general chemistry course telecasts. The surveys indicated that 63% (N=43) of the students attending the filmed course expressed a negative attitude at the beginning of the course. At the end of the course, only 40% of students expressed a negative attitude and as many showed a positive attitude; 20% did not express any opinion. On the other hand, only 11% of students in the control group (N=145), who had attended conventional courses and not watched the filmed course, expressed a favorable attitude toward the televised course. Individual interviews with the students in the treatment group with negative attitudes toward the television course showed that their attitudes were not as negative as first assessed. Two of the advantages of the televised course cited by the students were their ability to see the experiment close-up and the fact that they were better able to concentrate on the subject. Additionally, they indicated that the method also provided an opportunity for better-organized coursework and made it possible to cover a wider domain. Among the disadvantages students cited were that the telecasts were black-and-white and that the camera was unsuccessful in capturing some of the teacher’s movements. Another disadvantage the students pointed to was that no questions could be asked during the running of the movie. Only 11% declared that it was more difficult to take notes with this method compared to conventional classroom work. For 52%, there was no difference in this respect between the two methods and for 30%, it was easier than in a conventional course. The data thus pointed to a shared impression and the rest of this article will show how most of the advantages of this innovation were preserved as the evolution of the use of chemistry movies with a didactic aim continued and the practice was freed of many of its difficulties.

Glemser (1958) used a comparable technical device to show less visible experimental phenomena. Duffy and Walsh (1969) also filmed courses in order to allow students to catch up with their schoolwork. The researchers stated, however, that there was no difference between the examination results of the students who had attended the filmed courses and others. Many American universities, such as University of Detroit Mercy (1964-67), Montana State University (1962-66) and Kent State University (1966-67), developed courses known as "instructional television" (Barnard et al., 1968), which was later named "school television" in France.

An evaluation of a video course targeted for a few thousand students at the University of Illinois between 1968 and 1978 is reported by Enger et al. (1978). From the cognitive point of view, it was shown that the instruction was effective in the context of the examination results. Other effective aspects included good receptivity on the part of professors, instructors and students. The evaluation was also positive with respect to the replicability of the courses. It is indeed rare that a course can be reproduced identically for several consecutive years. Movies are expensive to produce but inexpensive to use.

Jegl et al. (1978) described a video course produced between 1972 and 1978. The students were shown a series of 41 movies following their traditional coursework. The content of the movies went beyond the frame of the experiment conducted in the laboratory (e.g., explosions of buildings, the animation of the dancing movements of a protein).

Fortman and Battino (1990) sacrificed some parts of chemistry experiments they had devised for students just to produce a spectacular show that would appeal to the curiosity of young people. At the time, it was only through a tool such as the video that a group of 15,000 students could be invited to watch a chemistry demonstration. The disappointment that the students may have felt in not being able to watch the experiment first-hand in the laboratory was compensated for with the high quality of the close-ups. The authors provided some discussion models and recommended that teachers use these for discussions after the movie. The subjects featured in the demonstration of experiments in the movies included among others, the simple properties of hydrogen, oxidation-reduction reactions in solutions and reactions of chlorine with metals. This was the first proclamation of a large-scale use of chemistry videos for pupils of middle school and high school.

Devices and Processes that cannot be Presented in Class

In France, the audio-visual department of École Normale Supérieure of Saint-Cloud created movies that made a pedagogical presentation of the industrial manufacturing processes of chemical products. Thus high school students were introduced to the processes of manufacturing nitric acid (16 minutes, 1962), sulphuric acid through the process of contact (16 minutes, 1962), ammonia (23 minutes, 1964), urea (16 minutes, 1964) and other chemicals on the basis of their own frame of knowledge at their educational level (chemical equations, concepts of oxidation-reduction, etc.).

The introduction of techniques of physiochemical analyses (Nuclear Magnetic Resonance – NMR, Gas Chromatography – GC, etc.) have appeared in university textbooks since the 1960's. Because of the high cost and unavailability of the instruments used in these analyses, Nienhowe and Nash (1971) began to produce movies to present these techniques to students. Movies thus made it possible to use instruments in teaching that could not be brought into the classroom, making at least parts of these instruments accessible to students.

Preparation of Practical Exercises

Rouda (1973) tried to avoid repeating descriptions of experiments that would be carried out as practical exercises. For this reason, he filmed some practical experiments (vacuum technique, use of a calorimetric bomb with oxygen, determination of vapor pressure, kinetic of a reaction of hydrolysis, etc.) performed by students themselves. It was observed that the students who actively participated in these movies became significantly familiarized with the experiments and their various aspects, including the apparatus, theories and calculations. The video technique greatly improved the students' communication skills, a noteworthy achievement considering that this occurred in 1972. The students watched the movies before starting on their practical experiments, which lightened the load of the curriculum program. The students' laboratory log-books exhibited a much better quality compared to previous years and it was also seen that they felt less stressed using the equipment needed in the exercises.

Pantaleo (1975) reported on the presentation of practical exercises with the help of movies in a first-year university class. Before performing the exercises, the students were invited to watch movies that showed some new devices and their mode of use.

Pantaleo indicated that the students were less prone to forgetting the important instructions of the previous session. Three sessions of acid-base titrations had been filmed. The students who had seen the videos used the balances better and performed the titrations with more precision. It appears that 90% of the students who had been prepared with the help of videos were successful in the practical exercises, whereas this percentage fell to 75% in the case of students who did not have the opportunity to engage in this innovative preparation.

To prepare their students for practical exercises, Russell and Mitchell (1979) produced about fifteen movies that show the basic techniques of quantitative analysis and their application to particular cases (e.g., weighing, preparation of a reference solution, use of a pipette or a burette for an acid-base titration, titration of the manganese in steel). The videos were freely accessible outside of the classroom but they were also being shown at the beginning of corresponding sessions. The time that the students were using to complete the experiments was thus reduced considerably, sometimes by half. A qualitative improvement in the experimental results was also observed. The reason for this may have been because students exhibited less anxiety as they set about discovering and using the intricacies of the equipment during their experiments.

Ferraro (1983) described the construction of a library of 14 3-7-minute movies which allowed the students to explore the laboratory equipment in the movie before actually confronting it in their practical exercises. Each movie consisted of a short introduction demonstrating the procedures presented by the instructor of the subject so that students were familiarized with the experiment they were to be performing (e.g., use of a Bunsen burner, a balance, a filtration, a distillation). The students were directed to watch the movie corresponding to the practical exercise, then fill out a questionnaire measuring satisfaction. The students found the movies useful (98%) and even very useful (65%); 90% asked for the project to be extended to other practical experiments as well.

Other types of experiments were used to prepare for the exercises, for example, allowing measurements to be taken from the movie (Haight & Jones, 1987). The oxidation-reduction reaction between a triiodide ion and an azide ion with a carbon disulfide catalyst that operates as a clock reaction was used for this purpose. This movie was a substitute for presentations that would have to be organized for 1800 students divided into 70 groups. The tests performed on the first 102 user students showed that they had a better understanding than those who had seen the experiment with their own eyes. The financial profit to be gained in this case is also evident as well as the lower risks related to the use of inflammable solvents.

Williams (1989) showed a specific method of calibration of an instrument of analysis (method of standard additions). This 35-minute movie described a demonstration of the theoretical relations that underlie this technique and its experimental realization. Goedhart et al. (1998) described practical experiments that integrated a video into the delicate domain of distillation. During their distillation experiment, students encountered several difficulties which were discussed and explained with the aid of the video. The quality of the teaching of distillation was improved by the use of the video. The video thus provided a positive experience. Browne and Auclair (1998) introduced basic techniques in experimental organic chemistry using the video: heating with back flow, use of a separating funnel, simple distillation, vacuum distillation, and the use of the rotary evaporator.

The Experiment, Nothing but the Experiment

More and more, experiments began to be filmed without a predetermined educational aim. For example, Fortman and Battino (1992) proposed the production of videos for 28 potentially dangerous, expensive and delicate experiments. Luoma and Yochum (1993) reported filming experiments to be incorporated into the content of oral examinations. The domain of general chemistry was furthermore explored in 32 movies (Laroche et al., 2003).

In 1997, Jacobsen and Moore began work to put together chemistry movies in a project called Chemistry Comes Alive! in order to place a complete set of movies at the disposal of teachers. With the introduction to the market of the first volume and as can be observed, the style that was adopted featured the use of close-ups in the filming of experiments (Jacobsen & Moore, 1997). Five other volumes have been made available since that time (Jacobsen & Moore, 1998, 1999; Jacobsen et al., 2000, 2001, 2002). Their use was described as stimulating as they were effective in encouraging students to perform the experiments enthusiastically (Bartholow, 2004).

Computer Graphics and Chemistry

Gelder et al. (1980) reported the use of images of synthesis. It appears that this was the first time that computer graphics were put into the service in chemistry education. The animation shows a cubic crystalline structure and its regularity in a movie of 7 minutes and 30 seconds. It allows the visualization of the elementary lattice and the number of particles in the lattice. Compared to a still picture in the domain of books, animation (the 3-D effect) gives life to this model of a perfect crystal, holds the student's attention, and creates conditions for better learning.

Interactivity: A Step Forward Toward the Multimedia

The laser-read videodisc (ancestor of the CD-ROM) brought a new dimension to the use of movies—interactivity. Access time to a movie had become shorter and a computer could now control the videodisc, thus making it possible to run a movie depending on the response given by the user. This interactive process thus allowed a certain form of educational customization. Arlene Russell (1984) from UCLA (University of California, Los Angeles) is recognized as the pioneer of the use of the videodisc in chemistry education.

Brooks et al. (1985) developed 30-minute computer-controlled movies for videodiscs during the same period. The authors reported that students could watch filmed acid-base titrations occurring around the equivalence point by exploring the process image by image, and possibly backward and forward. Interactivity developed even further as students actually performed the titration; if at any point, the student should miss a step, such as cleaning out the burette under the faucet, the final experimental value would be affected by this. Other experiments too were produced to support this context. Thus, Moore et al. (1996) announced the realization of 39 experiments (the spectacular oscillating reaction of Belousov-Zhabotinskii or the reaction of sodium with the dichlorine, etc.) for "introduction to chemistry" courses. The use of close-ups resulted in attractive movies and several demonstrations were accompanied with animations.

The Spread of Movies

In 1974, G. Warren Smith, an official of the Division of Chemistry Education affirmed that, even if a movie could not replace a teacher, placing this type of rich resource at students' disposal was beneficial because of its availability and the opportunity the method gave students to watch images again and again. It was also pointed out that movies served the purpose of providing students with knowledge in their own environments without having to come to the university (Smith, 1974). This situation also led way to the universities' opening to the rural environment if desired.

Attempts at broadcasting chemistry movies by the public or private television networks were less successful than movies in other scientific disciplines such as biology, earth sciences or the universe sciences, etc. Greenberg (1985) pointed out that the private televisions were airing the movies that also contained knowledge from medical fields. These movies contained information about dioxin (6 minutes), antagonistic properties of the medicine Naltrexone® (3 minutes), and synthetic analogues of the insect hormones (3 minutes), etc.

In 2001, a French textbook publisher published high school textbooks accompanied by CD-ROM's that contained movies of experiments (Micromega, 2001). About thirty short movies (between 20 seconds and 2 minutes) showing chemistry experiments included in the curriculum of the 10th, 11th and 12th grades were thus published for the price of a book.

Some chemistry textbooks used in American universities are accompanied with a CD-ROM that contains movies of chemical experiments (Silberberg, 2000) or non-interactive animations that display, for instance, mechanisms in organic chemistry (Vollhardt & Schore, 1999). An attempt was made to teach students chemistry topics with an active method that made a lasting impression in their minds.

Scientific film festival programs do not usually include chemistry movies. Research on the Internet reveals that there were only two chemistry movies in the more than one hundred scientific movies of Palaiseau in the 14th International Scientific Film Festival (1998). In fact, the two so-called chemistry movies were only on very broad aspects of chemistry—crystals and the life of Radium. There were no chemistry movies in the international science film festival held in France's Orsay in 2004; the festivals at Oullins, France or Quebec, Canada were not better supplied either. The disciplines promoted at these festivals were largely earth sciences, life sciences, health sciences and physics.

Rapid developments in the technology give rise to access many produced chemistry movies via internet. With the opportunity supplied by the internet, many movies serve teachers and students making learning and teaching easier by concreting chemistry. It is becoming more common everyday to find the videos of chemistry experiments and animations and simulations that explain abstract chemistry concepts on the Internet (Pekdag, 2010). Certain movies on the Internet can be critisized both for content and design. The presentation of the designed movies, which build meaningful relationships between the macroscopic and microscopic levels of chemistry, will serve students making the conceptual learning of chemistry easier (Pekdag & Le Maréchal, 2010).

Use of Chemistry Movies

After a half-century of using animated pictures in chemistry education, the time has come to assess and explore pedagogical perspectives in addition to didactic research.

Assessment

Chemistry movies with a didactic aim were initially used in the context of cinematographic tradition through the reproduction of whole courses or the production of documentary films on the chemical industry. Each time, the movies were long and in showing these to their students, teachers were forced to stay in the background. The cost of their production and the assessment of their use eventually created some limitations. Long movies were better able to portray chemical phenomena and thus had an undeniable advantage, but their integration into the educational environment was problematic because their producers kept their pedagogical aims fixed and did not adapt to the differences in environment. Today, it is important that a teacher knows how to integrate movies into the lesson during the course of study.

Another generation of movies based on a more restricted body of knowledge then appeared. It was a matter of making a dynamic presentation of how a piece of equipment or a laboratory technique was being used, how an experiment was being performed or displaying a microscopic representation by means of images of synthesis. Less expensive to produce, these movies could be used in a variety of situations: preparation for an experiment, demonstration of a lesson, as a tool of evaluation, etc. The movies were becoming an element of education but did not represent a full educational course. The teacher could demonstrate an experiment without encountering problems with materials, safety or the elimination of wastes, and also without worrying about whether or not the experiment would actually work. The teacher could interrupt the movie, comment on it or run it again. This provided many advantages over performing the actual experiment. With this evolution in the content of movies, it can be said that it became possible to eliminate parts of the teaching program that used to be preferred in a traditional curriculum and keep the parts which represented an advantage in the first long movies.

Perspectives

Students were spending more and more time in front of a screen; their parents had not spent this much time reading when they were the same ages (Rheingold, 1994). A new mode of acquiring knowledge thus appeared and it cannot be denied that students became conditioned to wanting to learn. Education should thus adapt to this new form of acquiring knowledge and indeed, in new educational environments in the future, teachers will be more aware of the process of learning.

Training of students

Movies are used in chemistry education to create effective and productive learning environments. The use of movies in chemistry education is reported to be successful in overcoming problems that cannot be eliminated with traditional teaching methods (e.g., understanding and conceptualization difficulties, misconceptions, motivation) (Sanger & Greenbowe, 1997; Burke et al., 1998; Ebenezer, 2001; Kelly & Jones, 2007; Dasdemir et al., 2008). Creating scientifically accurate, comprehensive and consistent mental models is indispensable in meaningfully learning chemistry. An educational program that includes chemistry movies is helpful to students in developing their conceptual understanding and forming high-quality mental models. Movies facilitate learning by allowing students to animate abstract chemical concepts in their minds (Williamson & Abraham, 1995; Cavanaugh & Cavanaugh, 1996; Goll & Woods, 1999; Sanger et al., 2000; Laroche et al., 2003; Yang et al., 2003; Marcano et al., 2004; Sanger et al., 2007). Ultimately an educational program that includes movies has been seen to create a significant increase in students' knowledge. Indeed, it has been set forth that movies have a positive impact on acquiring knowledge (Zahn et al., 2004; Michel et al., 2007).

Movies contribute to the development of a student's cognitive capabilities, including interpreting, critical thinking and problem-solving skills (Kumar et al., 1994; Hagen, 2002). The use of movies as teaching materials has a positive impact on a student's motivation (Kumar, 1991; Hagen, 2002). By effectively capturing the attention, movies ensure that students focus on the subject that is being taught and help them to retain the scientific knowledge they acquire (Duchastel et al., 1988). Additionally, movies also make it easier for students to remember the important points in subject matter (Kumar, 1991).

Important aspects of chemistry education are concerned, from a theoretical point of view, with the transformation of matter or the relation between structure and reactivity and, from an experimental point of view, with techniques related to the use of an analytical device or of glass objects in the laboratory. There is a dynamic aspect in both cases, and movies supply more advantages than photos or diagrams in building up knowledge. This is the direction that is taken by innovative ideas that are in harmony with research that stresses the importance of motivation and conceptual change. In the context of phenomena that take place at the microscopic level or of scientific models, animations provide students with the opportunity to see things that cannot be directly perceived. Because of their ability to present chemical processes in action, movies are an important teaching and learning tool in chemistry education.

The various limitations present in all classical experiments that must be performed in teaching environments prevent students from conceptualizing chemical phenomena that occur on a microscopic level. In contrast, movies provide students with the opportunity to watch microscopic chemical events with the help of active three-dimensional models. Students can thus see what is not directly accessible to the perception with the help of movies (Sanger et al., 2000; Ebenezer, 2001). In addition, movies are also useful in the teaching and learning environment in that they offer students a chance to observe rapidly-occurring scientific events and allow the teacher to show students in visual terms what has been explained orally in class (Robles, 1997).

Teachers may not be able to allow students to operate freely in the learning environment, either because the needed tools and equipment are too expensive to procure or because of the hazards that some experiments may present in the chemistry laboratory. Experiments in movie form, however, do not present hazards involving dangerous chemicals nor do they involve expensive tools and equipment (Hakerem et al., 1993). Movies are useful in teaching students about hazardous or problematic substances and introducing them to various types of equipment.

Ever since movies began to be used in classrooms in the 21st century, teaching and learning methods and strategies have continued to change. Making use of movies in the teaching environment has changed styles of teaching, creating a shift from a teacher-centered to student-centered instruction. Instead of remaining passive, students actively participate in the learning process (problem-solving, knowledge-building, etc.) in the classroom (Bernauer, 1995; Own & Wong, 2000). The use of movies in educational environments provides the opportunity to work together with the student. Students have the chance to discuss the chemical phenomena seen in the movie, communicating with each other to define and explain the particular chemical concept (Laroche et al., 2003). This leads to an interaction of knowledge among students and provides an opportunity to support the acquisition of knowledge through the building of a social structure (Solomon, 1987; Driver et al., 1994).

Teacher training

In the 1960's, Mellon and Dence (1971) filmed teachers who were carrying out general chemistry experiments. These 5-minute movies were then viewed by the teachers to serve as a basis for pedagogical improvement. Movies were thus used in teacher training to make teachers aware of their own deficiencies.

Filmed courses on chemistry education were then created. These were on the topics of the history of chemistry, specific methods of teaching, tools used in chemistry education and problems encountered in this domain (Burewicz & Gulinska, 1990).

Teacher training with regard to knowledge about available multimedia tools, their use and assessment, can be improved. In any given educational situation, today's teachers may not always know the benefits students can be expected to derive from the use of chemistry movies. Teachers must be aware of the benefits of using movies in a classroom environment. Some chemical reactions, for example, may be extremely risky for students to attempt. Instead of having students work with these reactions, using movies to demonstrate will eliminate any possible hazards. Also, at times when there is too little time to experiment or when the teacher is not totally satisfied with what has been taught, movies take on a complementary role in teaching chemistry.

Movies can be utilized in evaluating students or in the preparation of examinations. A traditional explanation in the form of a text could be replaced by a movie. The Micromega® CD-ROM for the 12th grade, mentioned above, presents some examples of such replacements.

Teachers might believe that with the use of movies in the teaching environments these movies will be taking on the responsibility of teaching in the classroom (Sutherland, 2004). Teachers must be informed so that they do not form this misconception. In addition, teachers must also be trained, not only in the technical aspects of using movies in the classroom, but in choosing appropriate methods and strategies that will incorporate movies in the learning process. There is a need for research in this direction.

Production of movies

Chemistry movies have been shortened since their first appearance. The cost of producing movies constitutes one reason for this; the skills of communication of teachers may be another. Students who have been accustomed to hearing professional voices and seeing the rehearsed behavior of actors and presenters on television might be critical of the filmed image of their teacher. However, for high level courses, when content difficult to master prevails over the form of explanation, conference courses might be the ideal solution. Such conference-courses carried out by specialists can be used in the universities as the basis of education on a subject that is presented in a movie. There are professional examples of such conferences on the École Normale Supérieure of Lyon website, available for consultation online. There are some perspectives on these conference courses but these must be developed.

Although movies of experiments have reached a satisfactory maturity, animations on the other hand, have not met their expected potential. Some animations can be criticized from the perspective of knowledge because the designer often does not have enough scientific knowledge about the particular model(s). The production of animations requires the joint effort of chemists, of persons who know the students well and computer graphics experts.

The multimedia, comprising movies and animations, must propose tasks for students and not be limited by the simple showing of movies. It is not enough to demonstrate chemistry, it is also necessary to activate different sensory modalities and create an effective environment that will improve learning and at the same time make students think more about the subject of chemistry.

Conclusion

The manner in which chemistry movies are so frequently produced today suggests that making movies of experiments or demonstrating techniques have had their hour of glory. The movies that have been produced are being offered to teachers and students and different learning environments benefit differently from these movies (e.g., introducing laboratory equipment, demonstrating rapidly-occurring chemical events, preparation for exams). It is important today to not only produce movies, but be aware of how these movies can be utilized in educational environments. Picking out suitable educational methods and strategies that will incorporate movies in the teaching environments is of importance for this reason. On the other hand, there has been recent research into the cognitive (learning more and better, memorizing, remembering) and psychological (motivation, pleasure of learning, etc.) benefits of using movies in chemistry education. It must be said, however, that learning styles using chemistry movies have as yet not been explored; this area must be examined. This will mean that it will not be enough to only produce movies; there also needs to be material written about these movies.

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