Television as a Source of Informal Science Learning for Pre-Adolescents: Design Considerations

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Abstract: Informal learning environments compel the design of activities that are both appealing and educational. This paper addresses issues involved in the design of science television programs for pre-adolescents, drawing more specifically on the case of a French-language series currently in production in Montreal. The program goals and format are discussed in relation to the target audience's developmental characteristics. Their attitudes toward science and their experience with the television medium. Such a series, it is proposed, should attempt to provide an emotional experience that is entertaining, involving and relevant as well as a cognitive experience that is challenging and empowering. Suggestions are offered as to how these qualities might be implemented in a television program. Experience with the series leads one to believe that the tenslon between learning goals and an entertainment format may be resolved creatively.

Résumé: Les contextes éducatifs non-formels nécessitent la conception d'activltes qui solent à la fols attrayantes et informatives pour le public-cible. Cet article aborde la problématique de la vulgarisation scientifique à la télévlslon en s'inspirant plus spécifiquement d'une série québécoise pour les pré-adolescents. Une telle série devrait s'efforcer de rejoindre le télespectateur sur un plan affectif en lui proposant une expérience divertissante, engageante et pertinente. La série devrait eéalement créer une situatlin stimulante et gratifiante sur le plan intellectuel. Des exemples concrets sont offerts pour illustrer comment ces objectifs peuvent se traduire dans la réallsatlon d'une emission. L'expérience demontre qu'il est possible de concilier des objectifs éducatifs avec un format de divertissement propre à la television.

INTRODUCTION

Formal science education prior to college is expected not only to provide basic training to future scientists, but also to impart tomorrow's adults with a working knowledge of science and technology. The limitedsuccess of curricular programs in achieving this ambitious goal has been the subject of much concern among educators, both in Canada and in the United States (SCC 1984; NSTA, 1984). Although no one would quibble with the importance of forma1 schooling and the necessity of working toward the improvement of science education, it is easy to lose sight of the science learning that also takes place in informal contexts. Indeed, children can also learn a great deal from their parents, from their peers, from extra-currricular activities such as science clubs and museums as well as from the mass media. Television in particular has unique advantages as a potential source of information about the world: it can overcome time and space barriers to present knowledge, experiences, unique views of phenomena and inspiring role-models that would otherwise remain inaccessible as direct experience for the majority of children. Given that children in Canada spend close to 20 hours a week watching television (Caron et al., 1990), it seems worthwhile to consider how to take advantage of the wide availability and strong appeal of television to complement the goals of formal science education.

On first thought, there may be an inherent paradox in wanting to promote science through television, a paradox that stems in great part from the commercial nature of the television medium. First, science programs have to contend with serious competition from expensively-produced entertainment programs for viewership. Second, children develop expectations toward the medium which may run counter to the educational goals of a science program. For instance, Salomon (1979) has shown how preconceptions of television as an 'easy' medium may lead children to invest less mental effort in processing television content than in processing print media. However, it will be argued in this paper that television does offer opportunities for informal learning about science to the extent that such educational programming successfully meets television on its own terms.

First, learning about things and learning about themselves figure among the main reasons children provide for why they watch television (Greenberg, 1974 in Palmer & Millward, 1986). Further, when educational programming is specifically designed with the target audience's needs and characteristics in mind, children do learn from television (i.e., Bryant et al., 1983). For instance, the series ***'3-2-1 Contact,'*** produced by CTW ***(Children's Television Workshop),*** succeeds in merging science content with an entertainment format by tailoring the program in accordance with 8 to 12-year-olds' social and intellectual needs while also taking into account their television preferences (Mielke, 1983). The relationship between enjoyment and achievement in formal learning situations is undoubtedly complex. Clark (1982) found that students learned less from the instructional methods they reported enjoying the most. With regard to television however, enjoyment appears to be a necessary component of the learning process. Children who reported enjoying 3-2-l Contact also learned more from the program (RCL, 1987).

The challenge involved in finding the right balance between entertainment and educational goals often leads concerned producers to turn to formative research to guide the design of a television program. "Formative research in television is a production and planning instrument that links producers and potential audience in the process of creating and refining a television product" (Caron & Van Every, 1989, p.17). Although formative research is by definition product-oriented, cumulative experience across a variety of programs eventually leads to the formulation of guidelines that have wider applicability (see for example Flagg, 1990). Formative research supporting the production of a French-language science television series for pre-adolescents entitled ***Les Débrouillards***[1] (i.e., 'The resourceful ones") (CYMS, 1988, 1989) will be used as a case in point to take a closer look at the design process involved in educational programming.

The idea for the television series originated from ***Agence Science-Presse*** (ASP), a press agency which has been active in promoting science for children in Quebec for over ten years. The overall goals of ASP are: 1) to satisfy children's quest for information about the world around them; 2) to awaken curiosity and foster a sense of wonder for the phenomena that surround them; 3) to promote a vision of science as an enjoyable and accessible activity; 4) to encourage children to engage in meaningful scientific experiences; and 5) to highlight the scientific and technological achievements of Canadian society. The agency publishes a monthly magazine ("Je-me-petit-débrouille") for 8 to 12 year-olds as well as science chronicles in major dailies and regional newspapers throughout Quebec and other parts of Canada. ASP also entertains close links with the ***Conseil du développement du loisir scientifique,*** a non-profit organization which oversees a network of science clubs. The agency considered television as a means of complementing and highlighting both the print media and the science clubs and of winning a larger audience to science as a leisure activity. Accordingly, one of the first undertakings of the formative research program was to review psychological, educational and communication research that would be helpful in formulating appropriate goals for the television series and suggesting a format suitable for the target audience.

SCIENCE, TELEVISION AND PREADOLESCENTS

Pre-Adolescent Development

In some ways, pre-adolescents may be considered an ideal audience for a science television program given their level ofcognitive development. Children of this age group have been described by Piaget as being in a concrete operational stage of thinking (Ginsburg & Opper, 1979). They have moved away from perceptually-bound reasoning and are able to think through the causes and consequences of phenomena on logical grounds much better than before. They are reality oriented, interested in understanding and mastering the world around them and open to new experiences.

At the same time, a television program needs to acknowledge certain developmental shortcomings in order to communicate effectively about science with an audience of this age. For instance, pre-adolescents have not yet fully mastered the formal reasoning skills required for scientific experimentation

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[1]Les Debrouillards is funded in part by the CRB Foundation and produced by Les Productions SDA in Montreal, Canada. The series is scheduled for weekly broadcast as of September 1990 on the French-language national television network, Radio-Canada. Formative research is conducted by the Groupe de recherche sur lea jeunes et les médias (Centre for Youth and Media Studies), Département de Communication, Université de

that involves systematic hypothesis-testing, Hence, they are more likely to be attracted by the manipulation of materials that produce visible effects than by the investigation of phenomena that are not directly perceptible. Scientific terminology that has become commonplace among adult professionals (i.e., molecule, genetic code, etc.) may be totally meaningless or only vaguely familiar to children of this age. As a consequence, they experience a great need for abstract concepts to be supported by concrete illustrations. To this end, television can be an important means of presenting visual models of phenomena, both static and dynamic,

Further, children apply their own intuitive conceptions of phenomena in trying to understand the program's content. Thus, the presentation of science topics should be tailored to acknowledge these levels of understanding in order to help children make sense of the information (Linn, 1986). For example, children of this age group frequently think that sinking and floating phenomena may be predicted on the basis of the weight of an object. Therefore, a program on ships could seize the forthcoming question in a child's mind and provide the adequate explanation of floating based on the density of materials (and the shape of an object), while providing a graphic overlay to help grasp the meaning of density which is not directly perceptible.

In order to appeal to pre-adolescents, a television program about science should also acknowledge the affective and social characteristics of this age group. Children between 8 and 12 years of age are gradually emerging from the family circle and developing a solid social network of their own (Gardner, 1982). This peer group solidarity is manifest for instance in team sports, social clubs and special interest groups. One way to build upon this social reality then is to highlight the phenomenon of science clubs as a means of sharing interests with their peers. Also, pre-adolescents are on the point of making their first career-related choices as they embark on a high school course. Children of this age are therefore at a critical point in shaping their attitudes toward science as a field of endeavor, whether it be as an academic, leisure or professional pursuit. Not surprisingly, they also share some common cultural myths about science which may play a part in their avoidance or early dismissal of science related activities. Given the centrality of this issue to a science program's goals, understanding the basis of these attitudes provides important clues as to how to address these misgivings.

Children's Conceptions of Science

One of the prevailing myths about science corresponds to a benevolent encyclopedic view of the scientific enterprise. Science is perceived as a distant storehouse of unquestionable truths which only need to be (painfully) memorized but which at least provide answers (sometimes all of them) to most practical problems which besiege us. This pragmatic orientation to science has been observed among children and adolescents (CYMS, 1989; Tremblay, 1985). What appears to be a positive attitude in fact overlooks the process of scientific thinking as a human undertaking that can be mastered and that can (and should) withstand evaluation. Therefore, an important goal for a science program should consist in conveying a more complete (and more critical) picture of the scientific process in addition to sharing actual research findings with the audience. This goal might be achieved in a number of ways: 1) underlining the merits of science as a logical, reality-based approach to problem-solving as opposed to magical thought or a blind trial and error approach; 2) pointing to the limitations of science in the face of social, economic or philosophical issues; 3) providing a view of science as an evolving discipline with changing theoretical viewpoints and as yet unanswered questions; and 4) showing how intuition and imagination are also necessary thought processes in the pursuit of scientific discovery,

Another misconception that tends to interfere with aspirations toward a scientific career pertains to the view of the scientist as an unusually gifted individual, usually male, with a meagre social life. In this respect, preliminary explorations of children's attitudes toward science (CYMS, 1989) are in accordance with findings from larger studies (i.e., Mielke, 1983). Therefore, another important goal of a science program designed for children should be to present a more realistic picture of scientists and scientific work. To begin with, the social dimension of scientists' professional lives may be highlighted to counter the stereotype of the solitary worker. For instance, the program might show the actual team work that is behind most research as well as scientists' involvement with broader contemporary social issues such as health, the environment, etc. The program can also strive to provide glimpses into scientists' personal lives, showing them to have mates and families as anyone else. One way to qualify the stereotypical view of the scientist as inordinately bright might consist in highlighting the range of personal qualities involved in scientific work (i.e., intuition, persistance, and leadership in addition to intelligence) and pointing to the broad gamut of science-related occupations that call for different profiles of abilities.

A recurrent finding in different cultural milieux is that myths about science may be more prevalent among girls than among boys (CYMS, 1989; Mielke, 1983; Tremblay, 1985). Boys are generally found to be more interested in science on the whole and to be especially attracted by technological achievements. On the other hand, girls are often less enthusiastic and tend to gravitate toward the natural and social sciences when they do show interest. Girls' reservations about science may be due partly to a limited view of scientific work which makes it seem incompatible with feminine qualitites. In some cases, girls' reluctance towards science has also been linked to a greater social consciousness of some undesirable consequences of technology (Mielke, 1983) although it appears that boys and girls share a growing common concern about environmental issues (CYMS, 1989). Therefore, efforts to highlight the creative and social dimensions of science, as discussed earlier, may be expected to benefit girls in particular. Another way for television to directly address these issues convincingly is to present female role-models successfully and happily engaged in scientific careers. By the same principle, role models for members of ethnic minority groups should reflect the increasingly diverse cultural mosaic of contemporary society

Children and Television in Quebec

Young Canadians, as their American peers, watch a great deal of television. Surveys over the last few years indicate that francophone Quebec children in particular areviewingbetween 20 and 25 hours of television weekly (Caron et al., 1990). With respect to genre, pre-adolescents especially enjoy action programs and situation comedies. Hence a survey among Quebec teenagers showing they intensely disliked science and news programs comes as no surprise (Tremblay, 1985). With respect to the format of television programs, pre-production research with the target audience (CYMS, 1989) revealed the same preferences for a narrative context, sophisticated visuals and realistic humor that have been found with larger samples of the same age group (Mielke, 1983). Given the cross-cultural similarities of Canadian and American pre-adolescents and their expectations of costly production standards, the translation of a successful television program for French-speaking viewers may at first appear to be a convenient and economical solution.

However, research on children's viewing habits and preferences (i.e., Caron et al, 1990; La Garde & Ross, 1984) runs counter to such a solution. Although French-speaking viewers watch English-language channels to some extent, and even though foreign programming is also available in translated versions, local programming is generally very popular. It is interesting to note in this respect that the popular foreign programs are exclusively entertainment fare. Indeed, children are often very critical of well-intentioned adaptations of foreign educational programs that appear less natural to them. On the other hand, the recent success of new educational programs (i.e., ***Club des 100 Watts, Robin et Stella,*** both from Radio-Quebec) indicates that young viewers can be very receptive to novel programs that are a reflection of their cultural reality. Given the competitive edge of entertainment programming and the goal of encouraging the viewer's identification with characters involved with science, it seems wiser to aim for a close cultural match in the hope of creating a more intimate rapport with the audience. In short then, an emergent television production is shaped by a multitude of factors, some general to children of that age group and to television in North America, others more germane to the specific cultural context of Quebec. Taken together, these research and programming considerations have inspired the production of a television series on science for pre-adolescents that will be presently described.

A SPECIFIC CASE STUDY

"Les Débrouillards" is a television series in the making designed to promote a better understanding of scientific phenomena and of scientific work and to generate interest and enthusiasm for the scientific realm. The program is meant to be entertaining as well as informative and gives special importance to humor. At the time of writing, the program featured three actors between 9 and 13 years of age as members of a science club under the amicable guidance of a young adult friend. Subsequently, the concept was redefined more along the lines of a magazine format hosted by two young adults and featuring as weekly guests children with special scientific interests or hobbies.

The program follows a modular structure comprised of three major types of segments: 1) studio segments featuring hands-on experiments and discussion of scientific phenomena; 2) field reports that consist of interviews with specialists as well as visits to various sites; and 3) comedy sketches. Briefer interconnecting segments include archival footage, information capsules and animated clips with a mascot borrowed from the print magazine mentioned earlier. Each episode revolves around a specific theme (i.e., the sun, flight, nutrition, etc.) which serves to introduce related concepts and applications from different fields of science and technology. The concepts are not linked to any specific curricular program but are selected among the array of possible topics as a function of their relevance to children's lives and their suitability for visual presentation. Following is a description of the pilot episode on sound which will serve to illustrate general points about the design process throughout the remainder of this article.

The pilot episode explored the nature of sound and its various manifestations in the world around us. The protagonists explained in concrete ways how sound is comprised of vibrations that travel through a medium, either gas, liquid or solid: for instance, they showed what happens when a gong is restrained from vibrating and what happens to ping-pong balls that are placed on an operating loudspeaker. An imaginary interlude on the moon provided an opportunity for talking about atmospheric conditions in an environment where air is absent. A visit to a hospital allowed a doctor to demonstrate how ultrasound technology is used to monitor the development of a baby in the mother's womb. Later on, a biologist explained how bats orient themselves by projecting sound waves while attempting to demystify children's fears about bats. Finally, an interview with a musician also provided the opportunity to demonstrate the applications of computer technology to modern music in an amusing fashion. In between these documentary parts, the children showed how to make a guitar and a stethoscope from simple materials. Their conversations, whether about dog whistles or the recording of their own voice, always centered on the program's theme of sound. The program ended on a humorous note with an opera singer demonstrating the power of her vocal cords.

TOWARD A DESIGN FRAMEWORK

The framework proposed here follows the premise that television viewing is both an emotional and an intellectual experience (i.e., Singer & Singer, 1983) and that both dimensions are essential for a sustained interest in science. Given the goal of fostering an interest in science among pie-adolescents via television, what might be the components of a successful viewing experience? First, it is suggested that the emotional appeal of such a program would rest on the viewer's perception of the program as being appealing and relevant. In addition, it is also suggested that a gratifying cognitive experience would be more likely if the program were experienced as challenging and empowering by the child viewer.

What production means are presently available that might facilitate such an experience? From a constructivist perspective (i.e., Wackman & Wartella, 1977) the total viewing experience ultimately depends on the interaction between the individual viewer and the program itself. However, guidelines may be useful in the process of designing a new program, as multiple decisions need to be made along the way. The framework outlined in Table 1 is therefore proposed as a working tool for the design of new programs on science as well as for the screening of existing science programs. In reality, these characteristics are closely interwoven and play out against each other to create a unique program style but they may also be examined separately for their specific contribution to the program as a whole. The list of suggested qualities is not

TABLE 1
Design Framework of a Science Television Program for Pre-Adolescents

Ideal Qualities of Program	Available Means
Emotional Level	
1. Appeal	a) Dramatic narrative b) Humor & stimulation c) Topic selection
2. Relevance	a) Life connections b) Identification c) Participation
Cognitive Level	
1. Challenge	a) Difficulty level b) Delivery and discovery c) Cognitive involvement
2. Empowerment	a) Children's conceptions b) Visual illustrations c) Language level

intended to be an exhaustive one but merely draws attention to some promising features.

Program Qualitites Related to the Emotional Dimensions of the Viewing Experience

Appeal. A science program needs to be appealing if it is to attract new viewers and hold their interest amidst a wide variety of programs. There are several ways of making a science program entertaining, which involve among other things, decisions about the genre that the science program will be molded into, the use of specific production features within the program and to some extent, the choice of the science topics per se.

Dramatic narrative. The narrative genre is widely used in television, both in dramatic and comical formats. The universal appeal of narratives is also manifest in science programming for the general public; scientists are often cast in the role of heroes conquering the forces of evil (i.e., disease, pollution,. . .) by means of their scientific discoveries (Silverstone, 1984). Although some concern has been expressed about the ideological consequences of implicitly presenting science as righteous and infallible by setting it within a narrative framework (i.e., Silverstone, 1984; Dornan, 1990), it seems reasonable to ask whether the narrative format may be a useful technique to awaken initial interest in science (even for adults). Moreover, pre-adolescents have acquired a good understanding of dramatic plots on television and are able to pick out relevant content from more peripheral content (Collins, 1983). Thus they may be more willing to follow through the history of a scientific discovery if it is set within a dramatic situation where the characters come to grips with unexpected events and personal problems in the course of their scientific pursuits.

In addition to its appealing qualities, the narrative structure may also serve an organizing function for the recall of information and help carry the viewer through less exciting material over the length of a program (Mielke, 1983). The narrative format has also been used with specific cognitive goals in mind. For example, 3-2-l Contact uses an adventure component to model inductive reasoning skills as the characters take on the role of detectives to solve crimes in their neighbourhood. Indeed, a critical outlook on science might be built into the narrative structure by showing that the protagonists make mistakes along the way and uncover more questions than they do answers. Whether such narratives will simply be perceived at face value by most viewers remains an empirical question but the dramatic component of television is an available means of enhancing the appeal of a science program.

Humor and stimulation. Comedies, it will be recalled, are a favorite genre of the target audience and it is therefore natural to ask whether there is room for humor in a science program. Humor in educational programming has been shown to increase attention and aid in the recall of information (Bryant, 1983). However, it is important to use humor and fantasy purposefully in a science program, in order not to undermine the credibility of the program or to confuse the viewer. Children of this age recognize the fictional nature of television in general but they are not necessarily adept at making fine distinctions about whether an event on televison could be a *possible* occurrence or a *probable* occurrence in real life (Dorr, 1983). Therefore, humor in the context of a science program should not serve to blur further the borderline between realism and fantasy.

Because of the natural tendency of some well-intentioned producers to make indiscriminate use of fantasy and special effects to make programs more appealing for children, a concrete example of misplaced humor will serve to support the point being made. One gag in the pilot program under study featured an opera singer appearing on a television show whose piercing vocal notes make the glass of the television screen fall apart. One drawback of relying too heavily on gimmicks of this sort is that pre-adolescents are likely to perceive such attempts at humor as "childish." Indeed, several children who viewed the program judged the exaggerated style of this segment to be incongruent with the realistic tone of the program. Further, it is unfair to lead someviewers to believe that such a phenomenon could take place unless it were pointed out as an event that calls for further investigation on the viewer's part.

When fantasy is used, it should be accompanied by cognitive signposts that clearly distinguish it from the realistic content of the program. For example, an animated character borrowed from the comic strip of the magazine that gave birth to the television series was a popular feature of the pilot episode. In this case, the animation technique clearly delineated these segments from the remainder of the program. In the series developed after the experimental pilot program, comical sketches were also intertwined with the science reports to provide pauses between the informative segments. Again, children of this age group can recognize clear variations between genres within a magazine format and interpret them accordingly Moreover, the interspersion of humorous segments within an educational program can actually facilitate learning possibly because it serves an alerting function to the material that follows (Zillmann et al., 1980 in Bryant, 1983).

The possible pitfalls involved in merging humor into a science program should therefore edge script-writers into finding additional creative solutions. In fact, to exclude humor totally from a science program might be perceived as reinforcing a common perception of scientific work as boring (a view that scientists undoubtedly do not share). Finally, the appeal of a television program may also be enhanced by the use of other production features (lively music, unusual camera angles, efficient visual editing and other special effects) that have also been shown to attract and sustain young viewers' attention and to facilitate information acquisition (Bryant, 1983). As a general rule then, educational programming should build upon the liveliness of television while aiming for moderate amounts of stimulation.

Topic selection. Finally, when the selection of topics to be covered in the program is not bound by curriculum constraints, one important criterion from the perspective of television should be the intrinsic appeal of that topic for children. A survey among 2,000 young readers of the JMPD science magazine

(GRJM, 1989) confirmed what the publishers and the science club workers had already gathered from their contacts with pie-adolescents over a number of years. They were especially interested in the biological sciences, technology, outer space and the environment. Therefore, a special effort can be made to link basic scientific concepts such as light, energy, etc., to biological and technological phenomena. As a case in point, the topic of sound provides the opportunity to explain how bate are special animals because they rely on sound waves to orient themselves in their surroundings and how ultra-sound technology allows us to monitor a baby's development in its mother's womb. Another way to generate interest in the subject matter might be to take advantage of children's fascination with the unusual and to link the topic under scrutiny to odd inventions, world records or even superstitions, whenever possible. For instance, hearsay about the danger represented by bats can be confronted with the biologist's explanations of bate' behavior. Such inserts provide natural opportunities to contrast 'magical' thinking with scientific thought.

Relevance

In addition to being attracted to the program as a potentially pleasant experience, the child viewer also needs to feel personally concerned by the content of the program. Thus, the program should strive to lead the viewer to a better understanding of the phenomena that are of importance to him or her, and encourage identification with the characters on the screen as well as active participation in the program.

Life connections. Whenever possible, specific topics should relate directly to the viewer's everyday life. For instance, two recent events in Quebec, a widespread blackout caused by a magnetic storm and an earthquake, provide a shared cultural experience from which to build episodes on electricity and geology. When one's daily routine has been upset and one's vulnerability suddenly revealed, it becomes relevant to understand the workings of nature. All subject matter, therefore, should be tailored to children's concerns and questions, whether these be of a capital or trivial nature. For example, a segment on aerodynamics should lead to a better understanding of how passenger planes fly but the application of those same principles to the flying of model airplanes and kites provides a better opportunity for the child to perceive those principles as immediately relevant.

Identification. The relevance of the science program for the child viewer may also be achieved through identification with the characters on the screen. Adult characters that are most likely to encourage identification are probably those who speak spontaneously and frankly to the audience while avoiding both an authoritarian or a compliant tone. Child characters need to be both believable and competent in order for child viewers to accept them as representative of their peer group (Bryant, 1983). Children of this age may indeed be quite critical of their peers on the small screen and do not easily forgive slip-ups. It is also useful to keep in mind that children tend to identify with characters their age or slightly older while girls engage in cross-sex identification more frequently than do boys.

Participation. Finally the child viewer maybe more likely to experience the program as relevant on a personal level if it leads to some form of direct involvement. Hence, experiments should be selected and presented in such a way as to facilitate replication at home. It goes without saying that security guidelines are then of paramount importance. Viewers might also be invited to perform some of the simpler activities while viewing, thereby enhancing the meaning of the content. For example, vibrating an elastic band between one's teeth with ears covered and uncovered allows the child to compare different sound vibrations as a function of the path of the sound waves. Finally, children can also have a part in the program when they are encouraged to forward their comments, questions and suggestions to the producers. In the case of the program being discussed, viewers can extend their television experience by writing to the science magazine or by taking part in a radio talk show.

Program Qualities Related to the Cognitive Dimensions of the Viewing Experience

Pre-adolescents have mastered the basic symbolic tools of their culture and are eager to expand their knowledge base and to develop their specific talents as they begin to establish themselves as autonomous individuals. Thus, even though television may often besought primarily for entertainment, it would be unfortunate to overlook the potential gratification that can derive from a successful learning experience through television. Given that a program attempts to reach the viewer on an emotional level as was discussed above, it should also strive to provide a challenging and empowering experience on a cognitive level.

Challenge

Learning from the television medium can only take place if the content is novel for the viewer and is more likely to occur if the viewer is actively involved in the learning process. For a science program to be intellectually challenging for pre-adolescents, it needs to be designed at an appropriate difficulty level, strive to achieve the right balance between delivery and discovery and attempt to actively involve the viewer at a cognitive level.

level. Children of this age group are quick to resent content that is too easy and will simply ignore content that is above their ability For instance, most pre-adolescents know about the existence of different gases but they may not understand the respective properties of gases or the laws of expansion that explain why helium and hot-air balloons rise in the air. Thus, a presentation that simply focused on gas as one of the four basic elements of the universe might be dismissed as too easy; on the other hand, an overly detailed presentation on the molecular structure of gases might be considered too difficult. Ideally, finding the right level requires the combined expertise of science teachers and cognitive psychologists and a constant adjustment of the scripts as a function of children's reactions.

Delivery and discovery. Another important dilemma for a television series is how to achieve the right balance between delivery and discovery, that is between providing information and bringing children to find out the answers for themselves, an issue that is also prevalent in science education (Linn, 1986). Excess in either direction would likely be detrimental to the goals of the series, On the one hand, adhering too strictly to a discovery approach may slow down the pace of the program to the point of losing viewer attention or it might needlessly deprive some viewers from a learning experience. On the other hand, an emphasis on the delivery of information might lead to a more superficial integration of content. Piagetian theory suggests that learning takes place through a combined process of assimilation (e.g., absorbing information into one's existing mental structures) and accommodation (e.g., adapting one's mental structures to account for new information) (Ginsburg Opper, 1979). Therefore, a program might aim for an equilibrium between the two corresponding modes of presentation. For instance, interviews with science people might naturally involve a high degree of information delivery while demonstrations carried out by the actors themselves could more easily lend themselves to a slower discovery mode, at times involving mistakes along the way.

Cognitive involvement. Television producers may be more adept at information delivery and viewers themselves may have become accustomed to minimal cognitive involvement during television viewing. Salomon (1979) for instance observed that children spontaneously display less AIME (Amount of Invested Mental Effort) when they view television than when they read a book, unless they are prompted toward more active processing. Therefore, it is the discovery mode of learning that poses a special, albeit not an unsolvable, design challenge for television. A good starting point might be to have the characters themselves model information-processing tasks by asking questions and formulating guesses about the phenomena under observation. The formal features of television may also be used to suggest interpretive processes to the viewer (Huston & Wright, 1983). For instance, dramatic musical notes during an experiment may cue the child to observe more intently by suggesting that something has gone wrong; the juxtaposition of seemingly unrelated images in the context of a science program may suggest that there is a logical connection to be identified. More active mental involvement on the part of the viewer may also be encouraged by inserting questions and puzzles for children to answer while viewing. Attempting to raise questions in the viewer's mind in addition to providing answers appears essential not only to create a sufficient amount of challenge for the viewer, but also to convey a more realistic view of science as a dynamic research process.

Empowerment

As a complement to the question-raising experience, the viewer also needs to experience some cognitive resolution. Empowerment in the context of a science program for children involves taking every available means to make the content comprehensible for the viewer. The design of the progam should therefore acknowledge the conceptions children already hold about phenomena, as well as their need for concrete visual support and for clear language.

Children's conceptions. A first important issue to address is how to make the program match children's intuitive conceptions about phenomena whenever possible. If a program designer is unaware of how children already conceive of a particular phenomenon, he or she runs the risk that the explanations will simply bypass the viewer's understanding. Let's consider one example among others. Children tend to think that a heavier steel cube will displace more water than an equal size aluminum cube (Linn, 1986). If the goal were to demonstrate the displacement of liquids as a function of volume, one would then design the demonstration so as to acknowledge the particular bias that viewers already hold about the phenomenon. However, following the above discussion of the entertainment dimension, there should also be a motivating context for such a sequence, such as the need to salvage a valuable object from underwater.

Visual illustrations. Pre-adolescents' need for concrete illustration of abstract concepts was alluded to earlier. A special advantage of television is precisely the availability of a range of production techniques that can serve as visual support. Some research on televised information has shown that iconic modes of representation, such as images which bear direct resemblance to the referent, may in some instances be processed more easily than symbolic representations such as verbal language that are arbitrarily connected to their referent (Huston &Wright, 1983). For example, having ping-pong balls bounce off a blaring loudspeaker shows the effect of the vibration of sound waves. Further illustration of the structure of sound waves varying in frequency and amplitude may be achieved through animation. Other special techniques such as graphic overlays, acceleration and deceleration photography, micro-photography, etc., may prove useful for clear and compelling exposition of complex processes and invisible phenomena.

Language level. The verbal mode remains very important nonetheless since information presented simultaneously in both modes is generally better understood than information presented in either mode alone (Huston & Wright, 1983). Hence a final issue related to the comprehensibility of science content is the use of an appropriate language level, one that is scientifically correct while avoiding needless technical jargon. However, paralleling the concern of producers in making scientific information accessible to the viewer, is the legitimate goal of science of introducing children to specialized terminology. To this end, the characters should take time to explain difficult terms or better yet, act as role models finding out what the words mean even as they struggle with the correct pronunciation. the extent that the combination of these features helps the viewer experience genuine understanding within the limits of a television program, such a feeling of empowerment may gradually convince the viewer that science content is within his or her intellectual grasp.

RESEARCH PERSPECTIVES

Science education objectives and the reality of children's television may at first appear to be irreconcilable but this inherent paradox may actually pave the way for some creative programming solutions. In this article, several suggestions have been offered to increase the likelihood that educational programming will be a rewarding experience that children will both enjoy and learn from. Some of the principles are supported by experimental research while others are proposed as working hypotheses. In practice, research and creativity converge to bring about a partial resolution of the paradox between learning and entertainment; indeed most design decisions appear to intertwine in their objectives and actually serve this dual purpose. Since each television program is unique, formative research can assist in making decisions about the design of a specific program.

In order for educational programming as a whole to benefit from these efforts, summative research or the evaluation of a program's success in reaching its goals, is also an important undertaking. Learning from television may be assessed at a basic cognitive level, at a more affective level or at a behavioral level. Thus summative evaluation could explore to what extent a science series leads to increased knowledge about science, nature and technology, to a more positive attitude toward scientists and scientific work or to increased participation in science-related activities. However, television's special contribution to science education needs to be viewed in a long term perspective and in interaction with other sources of formal and informal learning (parents, other media, science clubs, etc.). In closing then, these three areas of inquiry are proposed as interesting avenues to further our understanding of television as an informal source of learning.

Television and the social environment. A first area of research deals with the expected influence of a television program in the context of home viewing that goes beyond audience ratings. More often than not, the family context is an important mediating variable in children's learning from television (Ball, Palmer & Millward, 1986). For example, more than half the viewers of 3-Z-l Contact did something as a result of viewing (i.e., conducting an experiment, visiting a museum, reading a book....) (RCL, 1987) but an enriched home environment was a significant mediating factor in doing so. As researchers pay more attention to family viewing we should gain a better understanding of how parents can play a more active role in their children's experience of television.

In addition, research might also focus on children's relationship with television in the home context as they interact with siblings and friends and as they engage in various activities while viewing such as doing homework, playing with toys and pets, etc., (Palmer, 1986). Such naturalistic observations would provide a clearer picture of the kind of learning that can be expected to take place and of how program designers might accommodate the actual viewing context. Extending the immediate social environment to include the child's peer culture would also contribute to our understanding of how a television program finds its way into a child's life context. For example, how children talk about a science program, if at all, with their friends would also be of interest in understanding the social pressures related to viewing preferences and the additional processing of television information that may take place after the initial viewing.

Television and other media. A second area of inquiry could focus on the interrelationship between television and other media. Television offers the possibility of reaching out to afar greater number of children than usually does a science magazine for instance. The connections between the two media can be mutually beneficial, not only in terms of promotion but more importantly as a way to extend learning opportunities that neither medium could likely achieve on its own. For instance, the possibility of referring the viewer to detailed instructions in the magazine allows the presentation of more challenging hands-on experiments that are informative and enjoyable to watch on television. Hence a summative evaluation could address the issue of whether and how the television series and its twin magazine complement each other in leading children to engage in science activities. Also, a radio talk show presently on the air gives children the opportunity to ask questions and to discuss with science experts as a follow-up to the television program. Children's use of radio remains largely unexplored. A profile of the children who avail themselves of this opportunity and the consequences, if any, on their perception and appreciation of the television series could provide additional insights on ways to extend the television experience.

A related issue is how children control their own viewing exposure through the use of videocassette recorders (see for example, Levy, 1989 and Dorr & Kunkel, 1990). Knowing whether a science program would actually be recorded by the child and if so, whether the tape would be used for repeated viewing, selective viewing or modified viewing (i.e., slow motion) might provide important clues as to the appeal of a program and the kinds of learning that might be associated with different viewing experiences.

Television and school. A third area of inquiry could address the relationship between the science television series and the child's experience at school. The television series has opted to remain independent from the school curriculum in order to favor the spontaneous involvement characteristic of informal learning environments but these two areas of children's experience are likely to overlap (i.e., 1982 in Bryant, 1983). Although we should probably expect a reciprocal interaction between school learning and learning from television, some important questions remain about the connections between these two realms. Will teachers decide to use the television series in their science classes and if so, would children's perception and appreciation of the program change as a consequence? Will children themselves bring television into the school by using it for their assignments, talking about it in class or making direct suggestions to their teachers on the basis of the series?

The voluntary involvement of learners in informal situations such as television viewing compels program designers to search for ways to make science content appealing and relevant as well as challenging and empowering. Some of the principles that emerge from this practice as discussed in this paper might also apply to formal learning situations. Hence research that would focus more specifically on the relationship between school and television might eventually benefit both educational programming and curriculum development. Ultimately, we may want both formal and informal situations to merge as much as possible with each other if learning about science is to be both enjoyable and successful.

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