- For six of the eight episodes, significantly more children in the *CRO*-group recalled educationally relevant material (e.g., specific devices and how they worked) than the *CSD*-group (e.g., geography content).
- The *CRO*-group displayed a higher level of knowledge on at least one comprehension measure for each of the four topics that were investigated in this study. Moreover, the *CRO*-group's overall comprehension scores were significantly higher than the *CSD*-group's for the Catapults, Timekeepers, and Buoyancy topics and was marginally higher on the heat and insulation topic.
- For each interview topic children in the *CRO*-group were significantly more likely to rank the devices correctly and consistent with the episode.
- And finally, for three of the four interview topics children in the *CRO*-group generated significantly better explanations of the principles underlying the devices than the *CSD*-group did.

The effect on comprehension was especially strong for the girls and low science achievers. Whereas the girls in the *CSD*-group performed significantly below the level of the boys in both groups, the girls in the *CRO*-group performed significantly better than the *CSD*-girls and at the same level as the boys in both the *CRO*- and *CSD*-groups. This is in contrast to the findings from the Season I evaluation where the boys in both groups scored higher than the girls on two occasions. In addition, on the third and fourth interviews many of the differences between the two groups can be attributed to the better performance of the low science achievers in the *CRO*-group compared to the low science achievers in the *CSD*-group.

Interest and Comprehension

To examine whether children's comprehension of specific topics was related to their interest in the topics, we compared children's comprehension scores to their interest ratings

and activity choices for two of the topics (i.e., catapults and timekeepers). Major findings include:

- Within the *CSD*-group, children who received low comprehension scores on the catapult interview were significantly less likely to play with the catapult than the average and high comprehension scorers. However, there was no such relationship between catapult use and comprehension scores for the *CRO*-group.

CONCLUSIONS AND RECOMMENDATIONS

Overall, the results indicate that *CRO* has high appeal to children and has a positive impact on their interest in and comprehension of the science and technology concepts presented in the show. Many of the comprehension effects were stronger for girls and low science achievers, suggesting that *CRO* can serve as a powerful intervention for populations that are potentially "at-risk" for dropping out of science-related activities and developing negative attitudes toward science.

RECOMMENDATIONS FOR FUTURE *CRO* EPISODES

The results from this study provide strong evidence that *CRO* is a successful vehicle for stimulating children's interest in and comprehension of science and technology. We think that the changes in the show from Season I to Season II further facilitated children's comprehension, especially the low science achievers and the girls.

In general, the show is accomplishing the major goals of interesting children in science and technology and supporting their comprehension of these topics. We have no major changes to recommend for the show, however, we would suggest that the following aspects of the show be further strengthened and emphasized.

- We recommend that the child characters continue to be the active doers and

discoverers of the devices and concepts. Children in the study closely identified with the child characters in the show, and were particularly impressed when the child characters took the major role in the problem solving process and creation of the devices.

- Further reinforce the idea that revision is a natural process of problem solving and not indicative of failure by highlighting the partial success of the early-made devices, or how the performance of earlier devices led to the discovery of a better device.
- Make the connection between the modern times and the cavemen times more explicit. We think that showing the principles and the devices in two different contexts can further support children's understanding of the concepts, however, the link between the two contexts needs to be more explicit. We suggest that the devices or the goals of the devices be made more similar between the two settings or that there be some verbal mapping made between the devices and concepts in the two settings.

In conclusion, this study has shown that *CRO* is successful in familiarizing children with concepts in science and technology in a fun and appealing way. *CRO* had a significant impact on children's interest in and comprehension of science and technology, and this impact was often strongest for girls and low science achievers. As such, *CRO* is a valuable supplement to the reform efforts in science education.

ORIGINAL

Children's Interest in and Understanding of Science and Technology: A Study of the Effects of CRO

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with
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LEARNING RESEARCH AND DEVELOPMENT CENTER • UNIVERSITY OF PITTSBURGH

Conducted for Children's Television Workshop, New York, 1995

CHILDREN'S INTEREST IN AND UNDERSTANDING OF SCIENCE AND TECHNOLOGY: A STUDY OF THE EFFECTS OF CRO

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Anne Louise Fay, Ph.D.

Research Associate, LRDC

EXECUTIVE SUMMARY

In an attempt to contribute to the science education reform effort Children's Television Workshop (CTW) created *CRO*, an animated television series focusing on science and technology and shown on Saturday mornings. *CRO* centers on the adventures of an 11-year-old Cro-Magnon boy, his adopted Neanderthal family and the talking woolly mammoths who are their friends. In the course of their everyday activities, they confront obstacles that serve to motivate the use of a variety of scientific concepts and simple machines. The series aims to introduce six-to 11-year-old children to some basic concepts in science and technology, to stimulate their interest to learn more, and to show them that science and technology is an integral part of everyday life.

PURPOSE OF THIS EVALUATION

The Learning Research and Development Center was contracted by CTW to conduct and evaluation study of the eight episodes of the Season II of *CRO*. In line with the goals of the series, the three main goals of the study are:

- To assess the show's impact on children's interest in the science and technology topics presented in Season II's shows.
- To examine the show's impact on children's broader interest in science and technology topics and activities that were not presented in Season II's shows.
- To assess the show's impact on children's understanding of the science and technology principles presented in the show.

DESIGN

On the first two days of the study all children completed baseline measures and several pretest assessments of interest in science and technology. At the beginning of the next

session, children were assigned to the *CRO*-group or the *CSD*-group. Children in the *CRO*-group viewed all eight Season II episodes, two shows each week, on non-consecutive days. At the same time, children in the *CSD*-group viewed eight episodes of the Fox cartoon, *Where on Earth Is Carmen Sandiego. Where on Earth Is Carmen Sandiego* was chosen because, like *CRO*, it is an educational, animated series that airs on network television, but its content focuses on geography rather than science and technology. After viewing the second show of each week, children participated in a one-hour activity period, where they could choose among a variety of toys, games, and books that were either related or unrelated to technology. On the day following the activity period children were interviewed in same-sex, same-age pairs. Interviews focused on children's interest in the shows they viewed that week and on their comprehension of the concepts featured in the most recently presented *CRO* episode. Finally, at the end of the four-week treatment period, children completed several posttest measures of interest in science and technology.

PARTICIPANTS

The sample consisted of 101 inner-city children aged 5 -10, taken from three after-school programs in Pittsburgh (where *CRO* has not been broadcast). There were approximately equal numbers of girls and boys, predominantly minorities and low SES. Within each after-school program children were randomly assigned to either the *CRO*-group or the *CSD*-group.

MEASURES

We employed a multi-method approach to assess the impact of *CRO* on children's interest and comprehension. There were three types of measures: 1) paper-and-pencil, 2) in-depth interviews, and 3) behavioral observations. These measures included:

- **Baseline:** an assessment of prior knowledge about science and an interest scale to

establish children's initial attraction to items that were used in our behavioral measures.

- **Show Appeal:** a paper-and-pencil scale and interview questions that assessed the appeal of each episode.
- **Interest:** paper-and-pencil scales that measured children's interest in science and technology topics and activities before and after treatment, interview questions, and behavioral observations of children as they engaged in various technology-related and non-technology activities.
- **Comprehension:** in-depth interviews that measured children's free recall of the episodes they had viewed, plus sorting and explanation tasks that focused more directly on comprehension of the underlying science and technology concepts presented in four of the Season II *CRO* episodes.

RESULTS

Appeal

The appeal of all eight episodes of *CRO* was high -- significantly higher than all episodes of *Where on Earth Is Carmen Sandiego*. On the paper-and-pencil ratings between 79% and 92% of the children rated each episode of *CRO* between "Good" and "Great" and in the interviews between 88% and 92% of the children reported liking the episodes. This effect held regardless of age, gender, or science achievement. Reasons for appeal included the inventive problem-solving processes of Cro and his friends as well as more general positive attitudes toward the storylines and characters.

Interest

Several different and complementary measures were used to assess the impact of *CRO* on children's interest in science and technology. This multi-method approach was used to

provide a broad and valid picture of the impact of *CRO*. Major findings from the paper-and-pencil interest measures include:

- From pretest to posttest, children in the *CRO*-group (particularly girls), showed a significantly greater increase in interest in watching *CRO* and other science-based television programs (*Bill Nye the Science Guy* and *Beakman's World*) than the *CSD*-group. For both groups interest in non-science shows remained constant from pretest to posttest.
- When asked to rate their interest in doing a variety of activities, the *CRO*-group showed significantly greater pretest-posttest gains than the *CSD*-group in their interest in doing *CRO* -related technology activities (e.g., making a catapult). This effect was strongest for boys. There were no significant changes in children's interest ratings for non-technology activities or technology activities that were unrelated to *CRO*.

These findings were confirmed by interview data:

- Children in the *CRO*-group expressed an interest in acquiring more information about the technology content in *CRO* more often than the *CSD*-group expressed an interest in pursuing the educational content in *Carmen Sandiego*. This effect was statistically significant for six of the eight episodes and marginally significant for a seventh episode. Although children in the *CSD*-group said they wanted to find out more about the show topics, their reasons typically focused on how the topic related to their own personal experiences or prior interests (e.g., interest in an episode on chess because they played chess) rather than acquiring new information.
- On two of the four interviews, significantly more children in the *CRO*-group than the *CSD*-group reported engaging in unprompted activities related to the episodes viewed that week. For example, one girl reported using her mother's compact to see around corners after watching a *CRO* episode on mirrors and periscopes and

other children reported experimenting with floating objects in the bathtub after watching an episode on buoyancy.

Additional support for the impact of *CRO* on children's interest in science and technology comes from their hands-on behavior during four activity periods:

- During the third activity period, children in the *CRO*-group were more likely to engage in activities related to wheels and belts (e.g., build a toy using wheels and belts out of a LEGO kit) after viewing the episode which featured this topic. In addition, only children in the *CRO*-group engaged in an activity concerning timekeepers. The *CSD*-group's choices of *CRO*-related activities showed no such pattern.
- Overall, the *CRO*- and *CSD*- groups were equally likely to engage in *CRO*-related technology activities during the first activity period. However, while the *CRO*-group's engagement in such activities remained stable across the four activity periods, the proportion of *CRO*-related activities that were chosen by the *CSD*-group dropped significantly during the last two activity periods. This finding suggests that the *CRO*-group continued to be interested in the *CRO*-related activities but that the *CSD*-group's interest waned.

Comprehension

Comprehension was assessed via in-depth interviews. One focus of the interviews was on children's recall of the educational and non-educational content of the eight *CRO* and *CSD* episodes. In addition, two comprehension tasks were used; these focused on: 1) children's understanding of the principles underlying the devices in four episodes (Catapults, Heat & Insulation, Timekeepers, and Buoyancy), and 2) their ability to select the devices that would work best for particular purposes (e.g., no tank, an uninsulated tank, or an insulated tank as ways to create a hot shower). Some major findings were:

- For six of the eight episodes, significantly more children in the *CRO*-group recalled educationally relevant material (e.g., specific devices and how they worked) than the *CSD*-group (e.g., geography content).
- The *CRO*-group displayed a higher level of knowledge on at least one comprehension measure for each of the four topics that were investigated in this study. Moreover, the *CRO*-group's overall comprehension scores were significantly higher than the *CSD*-group's for the Catapults, Timekeepers, and Buoyancy topics and was marginally higher on the heat and insulation topic.
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The effect on comprehension was especially strong for the girls and low science achievers. Whereas the girls in the *CSD*-group performed significantly below the level of the boys in both groups, the girls in the *CRO*-group performed significantly better than the *CSD*-girls and at the same level as the boys in both the *CRO*- and *CSD*-groups. This is in contrast to the findings from the Season I evaluation where the boys in both groups scored higher than the girls on two occasions. In addition, on the third and fourth interviews many of the differences between the two groups can be attributed to the better performance of the low science achievers in the *CRO*-group compared to the low science achievers in the *CSD*-group.

Interest and Comprehension

To examine whether children's comprehension of specific topics was related to their interest in the topics, we compared children's comprehension scores to their interest ratings

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- Within the *CSD*-group, children who received low comprehension scores on the catapult interview were significantly less likely to play with the catapult than the average and high comprehension scorers. However, there was no such relationship between catapult use and comprehension scores for the *CRO*-group.

CONCLUSIONS AND RECOMMENDATIONS

Overall, the results indicate that *CRO* has high appeal to children and has a positive impact on their interest in and comprehension of the science and technology concepts presented in the show. Many of the comprehension effects were stronger for girls and low science achievers, suggesting that *CRO* can serve as a powerful intervention for populations that are potentially "at-risk" for dropping out of science-related activities and developing negative attitudes toward science.

RECOMMENDATIONS FOR FUTURE *CRO* EPISODES

The results from this study provide strong evidence that *CRO* is a successful vehicle for stimulating children's interest in and comprehension of science and technology. We think that the changes in the show from Season I to Season II further facilitated children's comprehension, especially the low science achievers and the girls.

In general, the show is accomplishing the major goals of interesting children in science and technology and supporting their comprehension of these topics. We have no major changes to recommend for the show, however, we would suggest that the following aspects of the show be further strengthened and emphasized.

- We recommend that the child characters continue to be the active doers and

discoverers of the devices and concepts. Children in the study closely identified with the child characters in the show, and were particularly impressed when the child characters took the major role in the problem solving process and creation of the devices.

- Further reinforce the idea that revision is a natural process of problem solving and not indicative of failure by highlighting the partial success of the early-made devices, or how the performance of earlier devices led to the discovery of a better device.
- Make the connection between the modern times and the cavemen times more explicit. We think that showing the principles and the devices in two different contexts can further support children's understanding of the concepts, however, the link between the two contexts needs to be more explicit. We suggest that the devices or the goals of the devices be made more similar between the two settings or that there be some verbal mapping made between the devices and concepts in the two settings.

In conclusion, this study has shown that *CRO* is successful in familiarizing children with concepts in science and technology in a fun and appealing way. *CRO* had a significant impact on children's interest in and comprehension of science and technology, and this impact was often strongest for girls and low science achievers. As such, *CRO* is a valuable supplement to the reform efforts in science education.

CONTEXT OF THE STUDY

As society relies more heavily on new technologies, an understanding of science and technology becomes increasingly crucial for successful participation in the daily workings of our world. Yet, an increasing number of young people are emerging from elementary and secondary schools with an inadequate understanding of science and technology (National Science Board Commission on Pre-College Education in Mathematics, Science, and Technology, 1983). Furthermore, fewer students are actually pursuing science and engineering as their college major and as potential careers (US. Congress, Office of Technology Assessment, 1988a, 1988b). Many white males have moved away from science and engineering and have chosen majors in business instead, and both females and minorities, specifically African-American, Latino, and Native American citizens are still underrepresented in science and engineering. The cause of the decline in these fields at the college and professional level has been traced back to elementary school, where shifts in attitudes towards science and technology begin to emerge.

Young children begin school with positive attitudes towards technology but their attitudes decline during the elementary school years. Even in elementary school children begin to rate science as one of their most difficult courses, and by eighth grade many students rate science as one of their least favorite courses (Howe, Blosser, Suydam, Helgeson, & Disinger, 1987). Although all children show a decline in positive attitudes towards science through the elementary and secondary school years, the most notable decline occurs in females and minority students. For instance, one national study found that the gap between the percentage of males and females who liked science increased from 3% in grade 4 to 17% in grade 12 (The National Education Goals Report, 1994). Within both the female and minority populations, attitudes show a significant decline by fifth grade (Fennema & Sherman, 1978; James & Smith, 1985; Schreiber, 1984).

Several factors have been identified as contributing to children's declining interest and increasingly negative attitudes towards science and technology, such as, poor self-concept and inadequate science instruction in elementary and secondary schools. Studies focusing on the role of self-concepts and feelings of competence have shown that females and minorities, in particular, often have poorer concepts of themselves as "doers" of science and have a more negative view of the usefulness of science in their lives as compared to white males. For females, engaging in science activities fails to inspire feelings of confidence or success, and fails to capture their curiosity (Kahle and Lakes, 1983). Furthermore, because science is often viewed as "unfeminine," some females experience conflicting emotions about displaying the interest, in fear that their popularity would be affected (Schreiber, 1984). Minorities also express early negative attitudes towards science, which may affect their performance. As early as third grade, minority students start to perform at lower levels in science than do white students, with this gap growing over time (Dix, 1987). The stereotyping of science as a white male activity, and the influence of parents, teachers, and peers affect females' and minorities' views of themselves as potentially successful participants in science, and thus serve to discourage their interest and participation in the field (Beane, 1985; 1990; Hall, 1981; Kelley, 1981; Oakes, 1990). Another factor associated with declining attitudes towards science is inadequate or inappropriate instruction during the early school years. The early "dropping out" of science by children in general, and by females and minorities in particular, has been attributed in part, to the way science is currently taught, which may, in fact, steer children away from pursuing science further (Senate Report 101-412, 1990).

To combat some of these problems, new science curricula are emphasizing meaningful, more open-ended problems and hands-on experiences to help engage children's interest and facilitate their understanding. This change in emphasis is supported by research that has found that when children engage in activities of interest to them (i.e., that they have some knowledge of and that they value) they are more apt to engage in exploratory behavior, and set goals and

challenges for themselves (Renninger, 1992). Consistent with these findings, new instructional programs attempt to capitalize on children's prior interest in such activities as designing and building things, with the goal of supporting extensive exploration of the materials and concepts, which in turn can lead to further development of their knowledge and interest in the domain.

Over the past ten years there has been a strong commitment to improve the level of science proficiency for children at all ages. Educational researchers, teachers, and school districts have formed collaborative partnerships to design new ways for introducing students to science and showing them how science applies to their everyday world. While efforts to reform education in the science classroom continue, most experts agree that formal education alone is not sufficient to impact on children's interest and performance in science. Children's extra-curricular activities and informal experiences also play a critical role in their interest and performance in science and technology (Lockhead, Thorpe, Brooks-Gunn, Casserly, & McAloon, 1985; Maccoby & Jacklin, 1974; Tsai & Walberg, 1983). For example, between the ages of nine and seventeen, girls report participating in fewer science- and technology-related activities than males, such as playing with magnets and mirrors, and activities involving electricity, heat, solar energy, and erosion (Kahle & Lakes, 1983). The lower age level coincides with the time at which girls begin to report science as more difficult to learn than boys, and when the gap between girls' and boys' interests in science begins to increase (Keeves & Kotte, 1992).

As a result of these findings, several informal intervention programs have been developed to supplement the educational reform movement in schools. These programs focus on stimulating children's interest by providing them with experiences that can support their comprehension. Most of these programs focus on young adolescents, and in particular, girls and minorities. These programs often work through schools, afterschool programs, children's museums, and clubs such as the YMCA or girls' clubs. Unfortunately, similar to reform

efforts in the classroom, many of these programs exist at the local level, and are not widely available. Children who may benefit most from these programs are often unable to participate due to the lack of availability or the time, effort, and in some cases, financial constraints of the parents.

CRO AND EDUCATIONAL REFORM

Another important source of informal education, and one that avoids some of the problems associated with informal education programs, is educational television programming. In their contribution to the reform effort Children's Television Workshop (CTW) has created *CRO*, a television series aimed at six-to 11-year old children focusing on science and technology. *CRO* is different from CTW's other educational productions in two ways: 1) It is broadcast on network television (ABC), as opposed to public television. This change was motivated in part to introduce and engage a broader and more diverse audience to science programming than would be reached on PBS. 2) It is a fully animated, story-driven cartoon series, rather than a documentary or information format show like *3-2-1 Contact*. This change was implemented so that *CRO* would be competitive in the Saturday-morning viewing environment, which focuses primarily on entertainment.

CRO centers on the adventures of an 11-year-old Cro-Magnon boy, his Neanderthal family and the talking woolly mammoths who are their friends. In the course of their everyday activities, they confront obstacles that serve to motivate the use of a variety of scientific concepts and simple machines. The main part of each show is set in the Ice Age and is framed by modern-day sequences starring a Latina scientist, an African-American boy, and a well-preserved woolly mammoth. In the present day sequences, a problem arises that leads the woolly mammoth to introduce the science and technology theme by recounting a similar situation encountered by the characters in the Ice Age. The show follows Cro and his friends as they search for solutions to their problem and wraps up by showing the modern day characters using similar concepts and technology to solve their problem.

Season II of *CRO* consisted of 8 half-hour episodes, each focusing on different kinds of devices to introduce different science topics, such as using mirrors and periscopes for the

concepts of light and reflection, catapults for storage of energy, and a shower and water tank for heat and insulation.

The goals of *CRO* are:

- To entertain and reach a large audience on network television, while helping increase children's familiarity with and interest in basic scientific and technological principles through an introduction to the workings of familiar machines, gadgets, and simple tools;
- To help stimulate children's interest in science and technology by showing that they are not abstractions but integral parts of everyday life;
- To convince youngsters that discovering the workings of science and technology can be great fun.

PAST EVALUATION: SEASON I

In Season I, a summative evaluation was designed to examine the impact of *CRO* on children's understanding of some basic science and technology concepts. Specifically, the study focused on children's understanding of the concepts presented in four *CRO* episodes, and on their ability to apply these concepts to new, everyday problems. A secondary goal was to examine whether *CRO* affected children's interest in pursuing activities related to the episode topics. Children from grades two to four viewed four episodes of *CRO* (or four control programs) across a two-week period. After each episode, in-depth interviews were conducted with pairs of children from both the *CRO* -viewing and Control groups to assess children's comprehension of the science and technology concepts. Children were asked to solve a hands-on problem related to the concepts introduced in the show, and after they worked on the problem an interviewer probed them about their reasoning. After viewing all four episodes children were asked a series of questions regarding the importance of the topics and their interest in learning more and were given paper-and-pencil measures that focused on their interest in engaging in *CRO*-related versus unrelated activities. These measures asked children

to rate the importance of learning about specific topics, their preferences for kits and books related to the topics in the episodes, and their interest in joining *CRO* -related clubs -- inventors' and scientists' clubs. Major findings indicated that:

- *CRO* was highly appealing to all children who viewed the show;
- *CRO* had a positive impact on children's comprehension of the science concepts in two out of the four shows;
- *CRO* had a significant effect on some interest measures.

The two episodes that produced significant comprehension effects differed from the other two shows in three main ways: 1) they focused on devices rather than abstract principles, 2) the scientific content was more directly linked to the central problem of the story, and 3) a sequence of solutions was presented in which each solution built upon and improved the previous solution.

Given children's minimal exposure to the show (four shows within a two-week period), these effects on interest and comprehension suggest that *CRO* has the potential to have an important impact on children's interest in and understanding of science and technology.

CRO : SEASON II

Based on the findings and recommendations from the Season I evaluation, the following changes were made in the Season II episodes:

1) The science and technology concepts were made integral to the storyline. The strategies the characters used and the devices they designed to solve problems were made more consistently central to the plot. The concepts were revisited throughout the episode by having the characters successively refine a device or work on different devices with the same goal to accomplish a particular task.

2) The modeling of scientific behavior was increased. The episodes were designed to show Cro, the Neanderthals, and the mammoths frequently engaging in processes such as