Explaining the Insulation Devices

There was no significant difference between the two groups in their explanations for the different devices (Means = 5.1 for *CRO* versus 4.6 for *CSD*, Max. = 8). In both groups most of the children focused on the inadequate strength of the stream of water in the no-tank device, and over 50% in both groups focused on surface features or misconceptions in explaining the no lid device (e.g., "the snow will get in"). On the insulated tank device, there was a non-significant trend for the *CRO*-group to produce more conceptually correct explanations; 40% of the *CRO*-group (compared to 13% of *CSD*-group) focused on insulation as blocking the transfer of heat, explicitly referring to the lid and padding on the tank as preventing the heat from getting out of the tank. The *CSD*-group, on the other hand, tended to explain (erroneously) that the insulated tank was best because "the lid keeps the cold air from going in." Thus, although the overall differences are not statistically significant, the trend on the insulated tank suggests that *CRO* may have had some effect on children's understanding of how insulation works.

Timekeeper Interview

Overall Comprehension

As shown in Figure 14, the *CRO*-group displayed a better understanding of the concepts related to timekeepers than the *CSD*-group (Means = 8.8 versus 6.4, Max. = 14), $p < .001$. This effect was due to girls in the *CRO*-group (particularly low and average science achievers) performing better than their *CSD* counterparts, p's $< .05$.

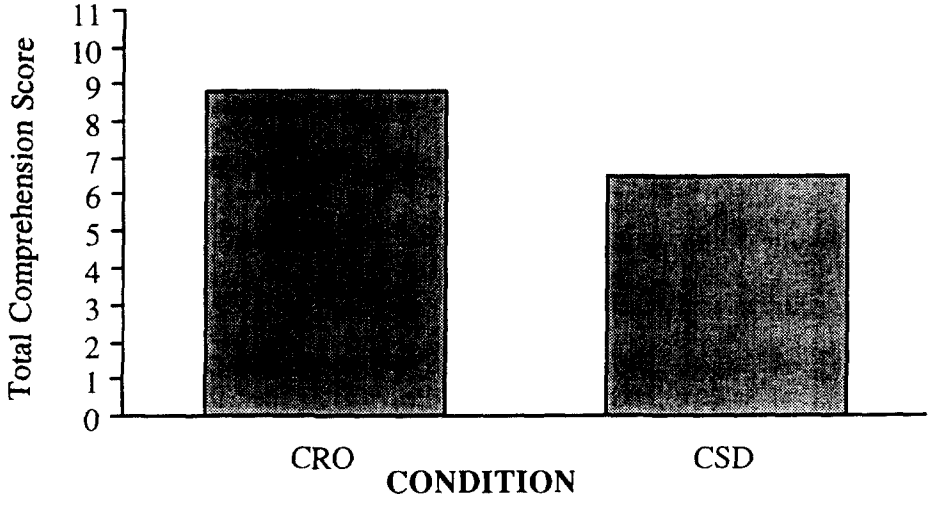

Figure 14. Timekeeper Interview: Total Comprehension Score by Condition

Ranking the Timekeeper Devices

Children received one or two points based on their ranking of the three devices that were illustrated in the *CRO* episode. The correct ordering, from best to worst was: 1) Sand Clock (or Water Clock); 2) Water Clock (or Sand Clock); and, 3) Pebbles and Bucket (see Appendix D.3 for these pictures). Children received two points if Pebbles and Bucket was ranked as the worst, otherwise they received one point.

Eighty percent of the *CRO*-group versus 54% of the *CSD*-group ordered the devices correctly (Means = 1.8 versus 1.5, respectively), $p < .02$. The two groups also used different strategies for sorting the devices. In the *CSD*-group, 25% sorted the devices consistent with the *CRO* episode and 29% used an alternative but correct ranking, compared to 78% of the *CRO*-group using the show consistent ranking and only 2% using the alternative correct ranking, $\chi^2 = 24.5$, $p < .0001$.

Explaining the Timekeeper Devices

Figure 15 shows children's explanation scores for the three timekeepers. The *CRO*-group generated more conceptually advanced explanations for the timekeepers than the *CSD*-group (Means = 7.03 versus 4.8, Max. = 12), $p < .005$. As with the Heat & Insulation interview, this effect was primarily due to the girls in the *CRO* -group performing significantly better than the girls in the *CSD*-group, $p < .005$. Children in the *CRO*-group were much more likely to refer to the rate, accuracy, or regularity of the timekeeper devices than the *CSD*-group, 35% versus 14%, respectively. For example, in explaining why the Pebbles and Bucket was the worst device, a young boy in the *CRO*-group said that "the monkey did them real fast, and the caveman did it slow, so it's not fair." In contrast, the *CSD*-group was more likely to focus on surface features: for example, a middle-age-group boy said the Pebbles was a good way because "if you always use the same number of rocks all the [baby-sitting] turns will be the same length".

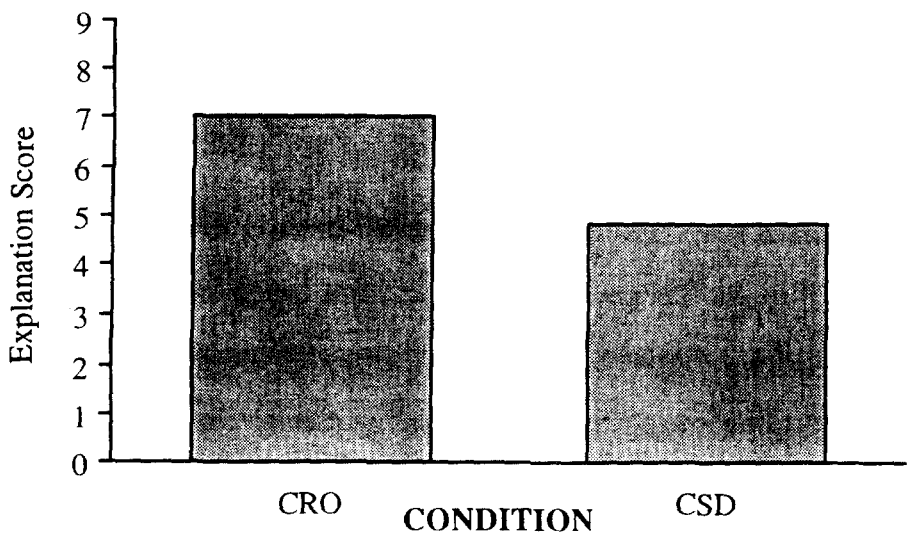

Figure 15. Timekeeper Interview: Explanation Score by Condition

Salvage/Buoyancy Interview

Overall Comprehension

As shown in Figure 16, the *CRO*-group showed better comprehension of the devices and the principles underlying buoyancy than the *CSD*-group (Means = 9.2 versus 7.6, Max. = 11), $p < .005$. This effect was due to girls in the *CRO*-group performing better than girls in the *CSD*-group, $p < .001$, and the low science achievers (girls and boys) in the *CRO*-group performing better than the low science achievers in the *CSD*-group, $p < .01$.

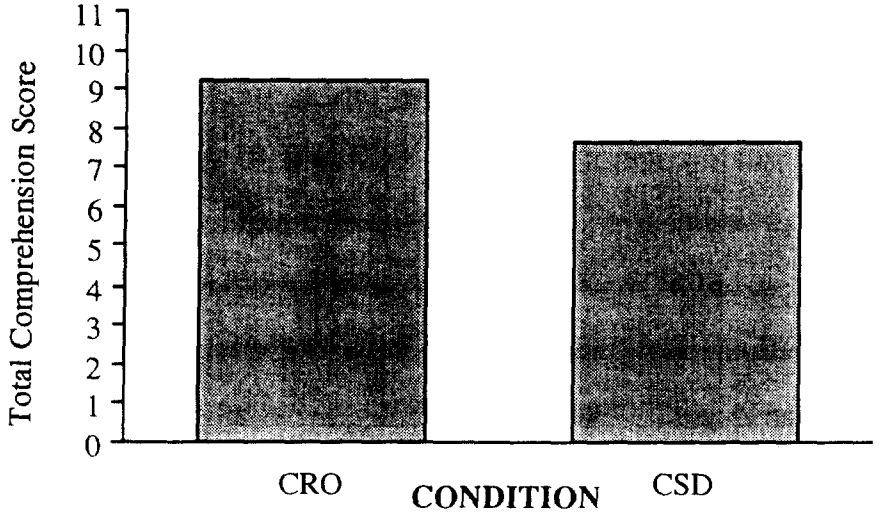

Figure 16. Buoyancy Interview: Total Comprehension Score by Condition

Ranking the Salvage/Buoyancy Devices

Children received zero to two points based on their ranking of the three devices illustrated in the *CRO* episode. The correct ordering, according to the episode, from best to worst was: 1) Logs and Balloons; 2) Pulling from the Raft; and, 3) Pushing the Log Underwater (see Appendix D.4 for these pictures). Children received two points if Logs and Balloons was ranked first or second best and one point if it was ranked as the worst.

All children in the *CRO* -group sorted the devices correctly compared to 81% of the

children in the *CSD* -group (Means = 2.0 versus 1.8), $p < .005$. The two groups used different underlying strategies to sort the devices, $\chi^2 = 20.1$ $p < .001$. Eighty-seven percent of the *CRO* -group sorted the devices consistent with the episode and only 13% sorted them in a different but correct way, compared to 39% of the *CSD* -group using the *CRO*- consistent ordering and 42% using an Alternative-correct ordering.

Explaining the Salvage/Buoyancy Devices

The *CRO* -group also generated more conceptually sophisticated explanations of how the devices worked compared to the *CSD* -group (Means = 7.0 versus 4.8, Max. = 9), $p < .005$. Again, this effect was due primarily to the better performance by the girls in the *CRO* -group compared to the girls in the *CSD* -group, $p < .001$, and to better performance by the low science achievers in the *CRO* -group compared to the low science achievers in the *CSD* -group, $p < .02$. When explaining the device with the balloons, over 80% of the *CRO* -group referred to the buoyancy of the logs and balloons (e.g., "balloons float up and logs float up too, and they will pull the statue up") compared to 50% of the *CSD* -group. When explaining why the log shown in one picture could or couldn't work, none of the children referred to the buoyancy of the log. All of the children in the *CRO* -group and 81% of the *CSD* -group focused on surface features or misconceptions, such as the weight or size of the log or the statue, explaining that the log was either too light in comparison to the statue (e.g., "If you covered the log with cement then it would be heavy enough to pull it up") or that the log was too heavy (e.g., "It's too heavy to push under the water.") When explaining why pulling up the statue from the raft would or wouldn't work, most children focused on the number or strength of the people pulling up the statue (e.g., "you need more people to pull because it's heavy"); however, 28% of the *CRO* -group compared to 8% of the *CSD* -group explained that it wouldn't work in terms of water displacement (e.g., "as you pulled the statue up the raft would go down.")

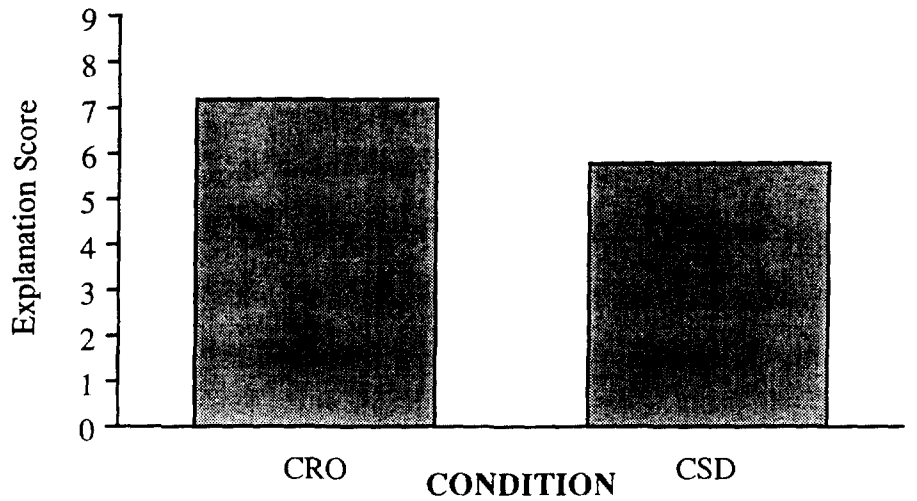

Figure 17. Buoyancy Interview: Explanation Score by Condition

Summary of CRO's Impact on Children's Comprehension.

The results from the in-depth interviews provide strong support for the positive effect of *CRO* on children's understanding of the science and technology introduced in the *CRO* episodes. First, the science and technology content was highly salient to the *CRO*-group, as indicated by the percentage of children spontaneously referring to educationally relevant content in their free recall, and by the high percentage of children in the *CRO*-group but not the *CSD*-group who ranked the devices in the sorting task consistent with the revision and improvement of the devices in the shows. Second, the science and technology principles were presented in an instructionally effective way. In every interview, the *CRO*-group displayed a higher level of understanding of the concepts than the *CSD*-group on at least one of the comprehension measures. Children in the *CRO*-group were more likely to rank the devices correctly and their explanations were often more conceptually sophisticated than those of the *CSD*-group.

This effect on comprehension was especially strong for girls: whereas the *CSD* girls performed significantly below the level of the boys in both groups, the *CRO* girls performed on par or higher than both the *CRO* and *CSD* boys. This is in contrast to the

findings from the Season I evaluation where the boys in both groups scored higher than girls on two occasions. Viewing *CRO* also had a significant impact on the comprehension of low science achievers. 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.

Thus the comprehension results suggest that *CRO* can help children acquire an understanding of science and technology concepts, and that this impact may be greatest for girls and, over time, for low science achievers.

KNOWLEDGE AND INTEREST

According to Renninger (1992), interest consists of two components: knowledge about and value of the subject matter. Although the present study was designed as an evaluation of *CRO* and not as a test of Renninger's theory, we examined our data to see if it could contribute to our understanding of interest in terms of these variables.

To investigate this issue, we analyzed the relationship between children's total comprehension scores, their ratings on the paper-and-pencil interest measures, and their selection of related activities during the activity periods for two of the topics in this study, Catapults and Timekeepers. These two topics were chosen because, of the four episodes tested for comprehension (Catapults, Heat and Insulation, Timekeepers, and Buoyancy), these two were also covered in both the pencil-and-paper interest measures and hands-on activities.

The only marginally significant effect we found was a relationship between comprehension of and interest in catapults. Moreover, this relationship was only significant for the *CSD* -group; 10% of the low-comprehension children in the *CSD* -group played with the catapult, compared to 45% of the average- and high-comprehension children, χ^2

=6.05, $p < .08$. This relationship did not emerge in the *CRO* -group; 38% of the low- and 30% of the average- and high-comprehension children in the *CRO* -group played with the catapult activities, respectively.

Thus, within one of the two topics examined, comprehension scores were related to interest scores for the *CSD* -group but not for the *CRO* -group. In this way, the present data provide some limited support for Renninger's theory that knowledge is related to interest. However, it is not clear why this relationship was not significant for both episodes or for both the *CRO*- and *CSD*- groups.

To examine these issues thoroughly, different measures might be needed. For example, the instruments developed for this study do not isolate value from knowledge. While responses to the pretest paper-and-pencil interest measures might be seen as indicators of value, some children's responses are likely to have been based on their prior knowledge of the topics as well. A true test of Renninger's theory would require independent measures of knowledge, value, and interest. In addition, a variety of methods have been used to assess comprehension in the past, and they have not all produced the same results; for example, comprehension measures that rely upon hands-on or more structured problem-solving tasks have shown different results than measures that rely upon verbal explanations (e.g., Bullock, 1984; Siegler & Jenkins, 1989; Fay, 1995). It is possible that other measures of knowledge, value, and interest might have produced data that supported Renninger's theory more clearly.

Finally, we need to learn more about the mechanisms that underlie how interest develops. Although the current study provides support for the claim that *CRO* has a positive effect on both knowledge and interest, more research needs to be done to understand how the mechanisms of development interact with knowledge and value and how interest can be maintained over time.

CONCLUSIONS

Overall, the results indicate that *CRO* has high appeal to children aged five to eleven. Almost all children rated the episodes as great or very good, (which was significantly higher than *CSD*) and their reasons for liking the show often focused on the problem solving process and the educational content. Although girls initially found the show less appealing than boys, by the second episode they rated the show equally as high. Furthermore, these high ratings remained stable across the eight episodes. These results, which are consistent with the findings from the first season evaluation, clearly indicate that the show and its science and technology content are appealing to children in this age group, and that it crosses a wide range of specific topics.

The results also suggest that *CRO* has a positive impact on children's interest in science and technology topics and activities introduced in *CRO*. First, children in the *CRO* -group showed an increased interest in viewing *CRO* and other science programs as compared to the *CSD*-group. Second, after viewing the Wheels & Belts episode, the *CRO* -group was more likely to engage in activities related to these episodes than on other activity days. Third, only children in the *CRO* -group engaged in the Timekeeper activity. Fourth, the *CRO* -group was more likely than the *CSD* -group to pursue activities outside of the activity period that were related to the content of four episodes (i.e., Mirrors & Periscopes, Catapults, Traps & Triggers, and Buoyancy), even though they had not been prompted to do so. Fifth, the *CRO*-group reported a greater interest in finding out more about the educationally-relevant content of the episodes. And finally, according to the paper-and-pencil measure, the *CRO* -group showed a significant increase in interest in doing *CRO*-related activities as compared to the *CSD* -group. In this last measure, the greatest impact was on the average science achievers, who indicated the lowest interest in *CRO* -related activities prior to the study.

Indeed, those children who did not watch *CRO* showed evidence of declining interest in science and technology. Prior to treatment, children in both groups tended to rate the *CRO* -related technology activities as interesting and the boys showed an initial preference for engaging in these kinds of activities over non-technology activities. However, while children in the *CRO* -group maintained their interest in the *CRO* -related activities across the four activity periods, children in the *CSD* -group showed a decline in interest in doing *CRO* -related activities and were less likely to choose them after the first and second activity periods. Thus, although the *CRO* topics were initially appealing to children, without the benefit of viewing *CRO* children lost interest in these topics over time.

The results also provide strong support for the positive effect of *CRO* on children's understanding of the science and technology concepts introduced in the *CRO* episodes. In every interview, the *CRO* -group displayed a higher level of understanding of the concepts than the *CSD* -group on at least one of the comprehension measures. 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 devices than the *CSD* -group.

The effect on comprehension was especially strong for the girls; 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 girls on two occasions. Viewing *CRO* also had a significant impact on the comprehension of low science achievers. 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. Thus, the comprehension results suggest that *CRO* introduces children to science and technology principles in an instructionally effective way and that this impact may be greatest for girls and, over time, for low science achievers.

Methodological issues

The methodology used in this study provides important new insights into the different ways that interest can be expressed and measured. By using a multi-method approach for measuring interest (i.e., paper-and-pencil, interviews, and behavioral measures) we obtained a richer and more reliable picture of children of how *CRO* impacts on children's interest and how interest and comprehension are related. Pieces of evidence from the different measures converged and lent further support for the trends in specific measures. For example, the *CRO*-group's small but significant increased interest in engaging in *CRO* -related activities (as measured by paper-and-pencil ratings for doing *CRO*- related activities) was further supported by the interviews in which they reported engaging in and pursuing *CRO* activities and topics at home and by the high and sustained frequency of these activities in the activity period. Uncovering different ways in which interest can be expressed, and enabling evidence to converge from different methods, points to the value of a multiple method approach in future research.

The results also confirm some of the problems that can arise from using paper-and-pencil assessments. The inconsistencies and ambiguities found in the Club Interest data (e.g., some children picking specific clubs as favorites but giving higher appeal ratings to other clubs) and the uncertainties that some children expressed about what sorts of activities would take place in particular clubs demonstrate the need to make assessment items as concrete and specific as possible. Research on the relationship between attitudes and behavior has consistently found that the more specified and concrete the behavior or activity the more likely the measurement

instrument will pick up a relationship between expressed attitude and behavior (e.g., Wiegel, Vernon, & Tognacci, 1974). Thus valid and reliable measures of interest are highly dependent upon the specificity of the items in the assessment instruments.

RECOMMENDATIONS

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 for low science achievers and the girls. For the low science achievers, having the show focus on the development and revision of one device or a few devices with the same goal and underlying concepts, seemed to provide them with enough exposure and examples for them to make gains in their understanding. This aspect of the show probably facilitated girls' comprehension as well. Girls in the *CRO* -group performed as well as the boys in the *CRO* -group, which is in contrast with the results from the Season I evaluation where girls scored lower on two of the four comprehension measures than the boys in both groups. Furthermore, we suspect that the more active roles that the female characters played in designing Season II devices also served to attract the girls' attention and interest in technology.

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, there are a few points that the developers may want to keep in mind for future episodes.

- **Continue to have the child characters be the active doers and discoverers of the devices and concepts.**

Children's comments in the interviews suggest that Cro's ability to solve problems and learn was a very powerful and attractive aspect of the show. We think that having the child characters succeed in solving the problems and in learning how the devices they built worked established in the viewers a sense of confidence that they could successfully engage in these kinds of activities too. This may be an especially important aspect for the low achievers and girls, who may not view themselves as potentially successful in these kinds of tasks.

- **Further reinforce the idea that revision is a natural process of complex problem solving and not indicative of failure.**

Either through the conversation of the characters or explicit recognition of the partial success of an initial device, continue to emphasize what was accomplished or what was learned and how that knowledge helped lead to final success. Showing children that revision is a normal process may help them overcome negative attitudes about their own abilities when faced with initial failure. Furthermore, explicit focus on how you can learn from your mistakes can provide a model for children on the importance of reflecting on and analyzing your work, an important but often missing problem solving strategy.

- **Make the connections between the modern times and the cavemen times more explicit.**

We think that having the two settings is a valuable aspect of the show but that the linkage between the two has to be more explicit. Efforts should be made to make the principles underlying the devices and the goals in the two settings similar and explicit enough so that children can make the mapping between them. Although the mammoth

verbally maps the goals of the two settings, (e.g., trying to see over or around an obstacle) the mapping between the devices and the principles often requires an inference that may be difficult for children in this age group, especially the younger ones. If the mapping is to be verbal, we'd also suggest that Mikey, the child character, do the job rather than the mammoth. As mentioned previously children seem particularly attentive and attracted to what the child characters say and do.

Overall, we applaud the efforts of the show to encourage and support children's reasoning and interest in science and technology. The show provides an excellent complement to the reform effort in science education. The modeling of collaborative problem solving parallels the move in elementary and middle schools to increase team approaches. *CRO* serves as a good model for how children can work together to solve a problem by showing how to share and listen to each others' ideas. The show is also to be commended for its use of female and racial minority characters. As research suggests, girls and minorities lack access to appropriate experiences and role-models for science endeavors and *CRO*, by enhancing the positive roles of females and minorities is helping to combat this problem.

In conclusion, we believe that *CRO* is a valuable supplement to new educational programs and efforts. *CRO* focuses on hands-on, contextualized activities, thus encouraging a model of children as "doers" of science -- active participants who can make things happen in their environment.

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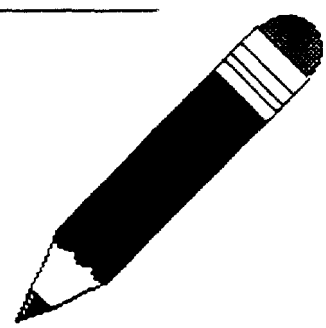
A.2

Name: _____

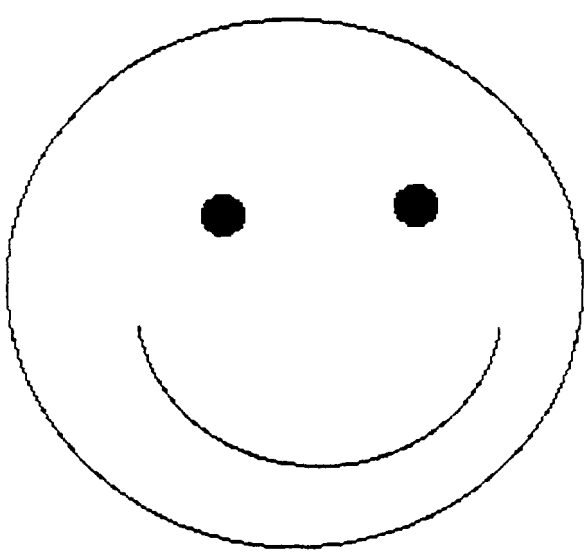
Age: _____

Grade: _____

School: _____



Thank You for your Help!



Appendix A :

Baseline Science Achievement Assessment

Below each question will be four answers. Circle the letter beside the answer that you think is the best.

Sample Problem

The sun's energy provides:

A. water and light

B. air and heat

C. water and air

D. heat and light

The best answer for this question is D.

DIRECTIONS: Read each question. Circle the letter next to the best answer.

1. Which of these will not float on water?

A. cork

B. oil

C. wood

D. marble

2. Which animals have hair?

A. birds

B. fish

C. mammals

D. reptiles

3. Which of these is wet and can be poured?

A. water in a glass

B. ice cube

C. salt shaker

D. ice cream cone

4. A ramp is most often used to move an object

A. up a pole

B. across a room

C. a long distance

D. from one level to another

5. Which of these is an example of work being done?

A. A bicycle locked to a fence

B. A person reading a bicycle magazine

C. A person peddling a bicycle

D. A person sitting on a parked bicycle

6. Sound waves are made by

A. heat

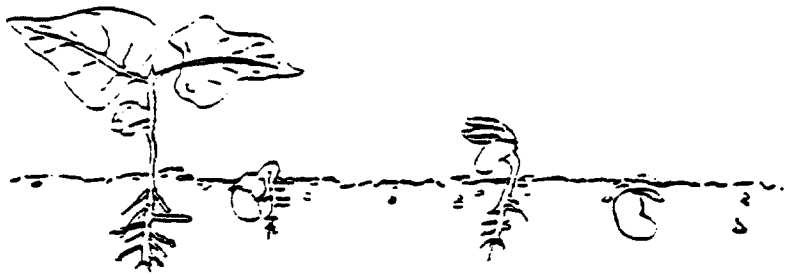
B. light

C. gravity

D. vibrations

7. Which line of plants shows the order of the life cycle of a bean plant?

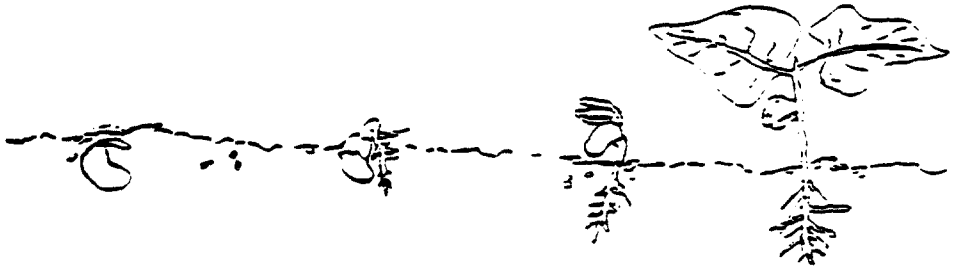
A.



B.

C

D.



8. Which object is small, hard, and sharp?

A. window

B. penny

C. thumb tack

D. flower