Learning Science From Children's Radio: Summative Evaluation of *Kinetic City Super Crew*

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The impact of four half-hour science programs aired on commercial radio was assessed in a causal-comparative between-groups study with prebroadcast and postbroadcast questionnaires. Of 253 fourth graders, 34% listened to one or more shows of the Kinetic City Super Crew series. Significantly more girls listened than boys. Listeners and Non-listeners did not differ on background variables of ethnic status, science attitudes, science reading and television viewing, and participation in seven of eight common at-home science activities. After broadcast, significant group differences, all favoring Listeners over Non-Listeners were obtained on five of twelve true-false statements and two of four science phenomena questions. Significantly more Listeners than Non-listeners engaged in home science activities, which included projects directly related to the series's content. The programs were not successful in affecting science attitudes or countering stereotypes. Overall, results were interpreted as suggesting the positive potential for using radio to expose children to science at an early age.

☐ Radio for children declined after the introduction of television, but radio designed especially for children is currently making a comeback in the United States. Single programs like *Kid's Corner* on WXPN-FM in Philadelphia (McKenna, 1993a) and 24-hour stations like Radio AAHS in the Twin Cities (Dean, 1992) draw relatively large listening audiences. The few research studies that have considered children's broadcast radio measured the size of listening audiences and appeal of features and formats (The Children's Audio Service, 1985; Giovannoni, 1992; McKenna, 1993b). In contrast, this study focused on the impact of radio broadcasts on children's learning, attitudes, and at-home activities.

The National Science Foundation funded the American Association for the Advancement of Science (AAAS) to develop a pilot series of four half-hour radio programs on science to be broadcast nationally for 8-to-10-year-olds. *Kinetic City Super Crew* uses a magazine format to present a science mystery story interspersed with informational features and a hands-on at-home experiment or project. The Super Crew are four teens who solve science mysteries by interviewing scientists, by traveling via train (hence, the term "Crew") to science research locations, and by applying problem solving techniques.

Formative Evaluation

Because children's responses to radio and science on radio are not well understood, an extensive formative evaluation period was planned for this project to inform the decision-

making process (Flagg, 1990). The research process for *Kinetic City Super Crew* involved six studies over a period of one year. The first five studies were formative evaluations that tested program elements or pilot programs in classroom environments, whereas the final study, reported here, evaluated the effects of the over-the-air broadcast of the series.

The first formative study, described in more detail below, was a preproduction evaluation that tested elements of the program and guided the design of the pilot format (Flagg, 1992). Then, a formative evaluation of the first half-hour pilot show diagnosed strengths and weaknesses of the format and led to revisions that were applied to the development of three more pilot shows (Flagg, 1993d). These three pilot shows were then subjected to formative evaluations to reaffirm the results of the first pilot test and to gather further audience feedback that would affect future programming of the series (Flagg, 1993a, 1993b, 1993c). Finally, at the same time that the latter formative evaluations occurred, the present summative evaluation of the weekly broadcast of the four pilot programs was carried out.

The first preproduction evaluation gathered feedback from third, fourth, and fifth graders in response to program elements that were proposed for the series format (Flagg, 1992). About 250 children from four urban and suburban sites across the country participated. In their classrooms, students answered appeal and comprehensibility questions after listening to each audio segment. The audio segments included the proposed radio theme song, a science mystery story, voices of nine children who auditioned as hosts, and six songs related to science themes. In addition, students' preferences were assessed in response to sets of printed descriptions of science themes and hands-on experiments. The data facilitated production decisions with respect to the choice of child hosts; styles of music; science themes; and the mystery story's pace, structure, language, and content density.

The first pilot program was evaluated by 460 third to fifth graders in seven school sites from urban California to rural Delaware (Flagg, 1993d). The goal was to gather feedback on the appeal of program elements and characters as well as appeal and comprehension of the mystery story and hands-on experiment. The pilot program, "The Crazy Cuckoos Caper," was a half-hour broadcast quality production, complete with professional voices, original music, sound effects, and credits. The program opens with the theme song during which is presented the problem of Claus the Clockmaker: Claus's clocks are telling crazy times and he needs the Crew's help. On the way to Claus's shop, the Super Crew meets a saxophone player who explains musical time. At Claus's shop, the Super Crew realizes that even the radio station's D.J. is reporting crazy times. While the Crew travels to the radio station, two brief informational segments are played that discuss how to tell time by listening to animals in the rain forest and how students in an elementary classroom tell time with water clocks that they are making. At the radio station, the Crew learns about the national atomic clock and decides to travel in their train to its site in Colorado. In the meantime, the Super Crew hosts describe the step-by-step procedure to make a water clock at home; night workers at a hospital explain the problems of keeping awake at night; and the Crew learns about body clocks from Dr. Elissa Ely, who is on the train as an adult resource for the Crew. Finally, in the conclusion of the science mystery story, the Crew and clock scientists in Colorado discover why the atomic clock is not working—the cesium had been replaced by silly putty.

The results of the formative evaluation of this program supported the magazine concept and the major format elements but also led to a clearer understanding of how to produce certain elements: the style, quantity, and function of music; the type and use of humor; the complexity and presentation style of the at-home hands-on project; the number, length, position, and content density of drop-in informational segments; and the scripting and voice quality of the Super Crew hosts and mystery story characters. Elements that were added to clarify the storyline and segment transitions included sound effect bumpers to mark segment changes and a Super Crew member to narrate.

With lessons from the pilot in mind, AAAS produced three more radio programs, and

these were evaluated in the same sites with the same procedures as the first program but with different classroom samples (Flagg, 1993a, 1993b, 1993c). Again, the formative evaluations focused on the appeal and comprehension of program elements. The results were used to confirm production decisions and to discover findings that were consistent across programs as a foundation for decisions about the future of the radio series.

Summative Evaluation

The five formative evaluations described above focused on gathering diagnostic feedback from the target age groups to improve the program design. The sixth study, reported in this paper, was a goal-oriented summative evaluation. This study assessed to what extent the series of four pilot programs, when broadcast on a children's radio station, achieved the intended outcomes of the series as defined by the producers. In defining the series's goals, the AAAS recognized the research that suggests that American children are falling behind in science achievement, that doing science at home is important to science knowledge and school success, and that children do not necessarily identify themselves with the field of science and scientists (AAAS, 1992). The producers were especially concerned with reaching and engaging girls and minorities, who are most at-risk in the field of science. Thus, this study was designed to evaluate the extent to which the series met its three major goals: (a) increase knowledge and understanding of selected science phenomena and science concepts; (b) engage children in active, hands-on science learning outside of school; and (c) foster positive attitudes toward science, countering stereotypes of science and scientists. The dependent variables measured in this study were listening behavior, appeal of the series, perceived learning, knowledge of program-related science facts, understanding of program-related science phenomena, definition of science, frequency and kind of at-home science activities, and attitudes toward science and science stereotypes.

Kinetic City Super Crew was produced to attract, motivate, and educate a voluntary home audience via over-the-air radio broadcasts. The consequence of this media presentation for the research design was a lack of direct control over the independent variable—the extent or nature of listening to the series. This resulted in self-selection of students into comparison groups of listeners and non-listeners; thus, a causal-comparative between-groups design was employed (Smith & Glass, 1987). Because the self-selected groups could have preexisting differences that might account for effects otherwise attributed to the radio series, antecedent variables were measured and tested including gender, ethnic background, science attitudes, and at-home science habits, such as exposure to science magazines, science television programs, and science activities.

METHOD

Subjects

Three elementary schools in southern Howard County, Maryland, were chosen because the signal of the new AM radio station could be received clearly and because the area's population is diverse in ethnic background. The summative study focused on fourth graders, the middle grade of the target audience range. In the three schools, a total of 253 fourth graders completed instruments *both* before and after the radio series as part of their classroom activities; 20.6% were minority students and 46.6% were females.

Programs

A new children's commercial radio station in the Washington, D.C. area began broadcasting seven days a week in the Spring of 1993. One month after its debut, the network aired four *Kinetic City Super Crew* programs, one a week for four weeks, on Tuesday afternoons at 4:30. Each half-hour program included a science mystery that the Super Crew solved by interviewing people and applying problem-solving techniques. Interspersed in the adventure story were brief informational segments on the pro-

gram topic and a hands-on experiment or project for listeners to replicate at home.

The first pilot program, "The Crazy Cuckoos Caper" (abbreviated here as TIME) is described in detail above. The design of the other three programs was guided by the evaluation results of TIME. To provide a feeling for the style and flow of these programs, a detailed description of "The Case of the Flushing Fan" (GARBAGE) is presented below.

The GARBAGE show opens with a rock-style train-beat theme song, during which Erica telephones her Super Crew friends because she thinks that her prized Michael Jordan trading card has been flushed down the toilet by her little brother. At the close of the song introduction, the Super Crew reporter/narrator, Joaquin, briefs listeners on the case background, and the Crew gathers in the train's control car to review Erica's problem. The Crew then takes the KC Express train to Erica's house (train sound transition), where Erica explains the events leading up to the card's disappearance. The Crew decides to explore the two possibilities of following the trash and the sewage. Throughout the story, the Crew makes the most of the grossness of this caper. ("Where does the sewer go?" "Only one way to find out." "Transform into sewer rats and explore the underworld of murky sewer stuff gushing below our feet?" "I think there's a cleaner solution.")

The Super Crew splits up to locate the card. In conversations with street workers, Annalee and Chantel learn the difference between a storm and a sanitary sewer and discover that the sewage ends up at a water treatment plant. Meanwhile, Joaquin and Alvin follow the trash truck to the landfill where they uncover the magnitude of the garbage problem as they dig through the residential trash. ("This is the sixth TV I've found today. I mean, what do people do, throw them out after a bad show?")

The Crew regroups for lunch at the train's club car (indicated by a few musical bars from the currently performing group). "Stuff growing" on one of their sandwiches generates a discussion about bacteria and fungi with Dr. Elissa Ely, the Crew's resident scientist. ("Most bacteria don't hurt you. A lot of bacteria live inside you, and some of them make important vitamins.") Subsequently, a "KC Express Passenger Information" bumper introduces a brief adult-narrated informational segment on packrats.

A musical transition introduces "Home Crew Hands-on"—a step-by-step description by the Super Crew of how to make a packrat time capsule at home. Listeners are encouraged to call an 800 number with a list of their capsule contents. Next are presented snippets of telephone calls from listeners who called the 800 number during the previous week and gave their project results or their opinions of the program. ("Hi, I'm Steven. I think the show is a great success.") Listeners are again encouraged to call in.

Back to the story, Joaquin brings listeners up-to-date with the search. Listeners follow Annalee and Chantel as they explore the steps of processing sewage in the water treatment plant (with sound effects and worker conversations). In conclusion, the Crew informs Erica of their lack of success, but Erica tells them that she found the card under her brother's mattress along with other stuff. ("The kid's a regular packrat.")

In the third program, "The Case of the Dancing Elephants" (SOUND), the Crew went to Africa to learn how elephants communicate with each other. During the show, they made musical instruments and learned about sound. Finally, the fourth program, "The Case of the Seedy Con Man" (SEEDS), focused on seeds and the function of cave birds in renewing the rain forest.

Procedure

Because *both* the radio station and the programs were new and because listening was voluntary, it was necessary to encourage students to tune into the programs. Five flyers were sent home with all fourth graders over a period of four weeks. The first flyer announced the series before it began and suggested that the student's class could win a special prize by listening. Each of the remaining flyers was given out on the day before a program, one each week. For each program, the associated flyer announced the listening time and radio

station frequency, posed the science mystery problem, described one of the four Crew members, and listed the materials needed for the hands-on activity. In addition, each student was encouraged to have an adult sign the bottom of the flyer to certify that the child had listened to the program. The class that returned the most signed forms would win a special prize. In fact, at the end of the broadcast period, all fourth graders received *Kinetic City Super Crew* hats and hands-on experiment cards.

Three days prior to the first flyer distribution, students in class completed a ten-minute prebroadcast questionnaire. This questionnaire did not mention the radio series and was not identified with the series. The questionnaire (described in detail below) established students' at-home science habits, science attitudes, definition of science and curiosities about science.

Students completed a postbroadcast questionnaire on the day after the airing of the fourth program. The questionnaire (described below) measured again students' at-home science habits, science attitudes, definition of science and curiosities about science. It also addressed students' image of scientists and their understanding of science facts and science phenomena discussed in the series. The timing of the questionnaire meant that recall of the first program (TIME) was measured three weeks after exposure; recall of the second program (SOUND) was measured two weeks after airing; recall of the third (SEEDS), one week; and of the fourth (GARBAGE), one day. Finally, the questionnaire determined students' listening behavior and their reactions to the programs.

Measures

Listening behavior. Students were asked in the questionnaire whether they had listened to any of the *Kinetic City Super Crew* programs and if so, to specify which ones. ("Did you hear a program about garbage and sewage?") To aid in identifying "real" listeners, two false programs were listed also. ("Did you hear a program about stars and galaxies?") Students also reported on whether an adult listened with them.

Program appeal. Listeners chose one of four scaled statements to indicate how much they liked or disliked the radio programs: "I liked the radio programs"; "I sort of liked the radio programs"; "I sort of didn't like the radio programs"; and "I didn't like the radio programs." In addition, students stated whether or not they would like to hear more programs.

Perceived learning. In an open-ended format, listeners were asked to list some of the new things that they learned from listening to the programs. The answers were coded as to whether or not they mentioned content specifically related to any of the four programs. Inter-coder agreement of two coders was 100% for 30 questionnaires drawn randomly from the sample.

Science knowledge. Factual recall of the radio programs' content was assessed after the broadcast period. A modified true-false approach was chosen over other formats in order to cover more content in less time and require less reading in an easy to understand layout (Ebel & Frisbie, 1986). For each of the four radio programs, students were presented with five statements and asked to check "all the ways that you think people can use to tell the time of day" (TIME), "all the sentences that you think are true about sound" (SOUND), "all the ways that you think seeds move from their plant to another place" (SEEDS), and "all the sentences that you think are true about bacteria" (GARBAGE). Three of the five statements were drawn directly from the program content, and two statements were related in content but not included in the program. Four of the five statements were true. Answers were scored correct or incorrect for each statement, and statement results were analyzed individually. The 20-item recall test had a Kuder-Richardson reliability of .66. For example, true-false statements for testing recall of the GARBAGE program are listed below.

Statements drawn from program:

- Bacteria can live inside you. (T)
- Bacteria can make important vitamins. (T)
- Bacteria can make sewage smell better. (T)

Statements not drawn from program:

- Bacteria is the green fuzzy mold on old bread. (F)
- Bacteria can help people mine metal. (T)

Understanding science phenomena. Postbroadcast open-ended questions addressed the scientific phenomena involved in the hands-on projects or the science mystery adventures. Students were asked to draw and write about (a) the operation of a water clock (TIME), (b) the distribution of water in a water glass musical instrument (SOUND), (c) the change in a random dirt sample when bagged and watered (SEEDS), and (d) the disposition of household sewage water (GARBAGE). Each question provided a context and a beginning picture for the phenomenon under consideration; for example, the question for the GARBAGE program showed small pictures of a bathtub, sink, and toilet leading to one drain pipe and read: "Erica lives in the city. Her bathroom has a bathtub, sink, and toilet that are shown below. Starting with the drain pipe, draw where the waste water goes and what happens to it. Write about what is happening to the water in your drawing."

In scoring the answers, one point was given for each component of the answer presented correctly, either in picture or written form. Because the complexity of the answers differed, the maximum scores differed also. The maximum possible score for TIME was 5 points; SOUND, 1 point; SEEDS, 1 point; and GARBAGE, 8 points. Inter-coder agreement was 97% for 30 questionnaires randomly drawn from the sample.

At-home science habits. In the prebroadcast questionnaire, students were presented with lists of five science magazines, five science television shows, and eight common at-home science activities. Students were asked to check the ones that they had read, watched, or carried out. In the postbroadcast questionnaire, students were asked to describe what science activities they had done at home in the last two weeks and what kind of science activities they would like to do at home. Coding for the latter two questions included the number of activities listed and whether or not any of the activities directly related to the series's content (i.e., time, sounds, seeds, garbage). Those who reported listening to any show were also asked to report on their attempts, if any, to do the hands-on projects. Answers were coded as to whether or not a project was tried and to which program it related. Inter-coder agreement for the questions on at-home science habits was 100% for 30 questionnaires drawn randomly from the sample.

Definitions of science. Both before and after the radio broadcasts, students were asked to write down what they thought science was. This open-ended question was considered experimental and meant to capture changes in categories of what students defined as science. Initial coding categories were determined through content analysis of 25 questionnaire answers from a pilot sample of fourth graders. Content analysis of 30 random prebroadcast questionnaires from the summative evaluation sample yielded an additional two categories (Inventing, People), which had not been mentioned by the pilot students. Typically an answer fit into only one of the eight definition categories below, which were scored dichotomously as mentioned or not mentioned:

- Experiments ("Doing experiments.")
- Inventing ("Trying inventions.")
- Knowledge ("Science is about earth.")
- Learning ("Learning new things.")
- People ("Newton.")
- Process (verbs related to observation, exploration, discovery; e.g. "Trying to find out new things"; "When someone discovers something new.")
- Tools ("Microscopes.")
- Other ("Science is mystery.")

Inter-coder agreement of two coders was 95% for 30 questionnaires drawn randomly from the sample.

Science attitudes. Both before and after the radio broadcasts, students' attitudes toward science were assessed with four statements in a Likert format, modified appropriately for a fourth-grade comprehension level. Thus, a four-point response scale was employed, and response

options were stated as full sentences:

1. Science is *fun*. Science is *sort of fun*. Science is *sort of boring*. Science is *boring*.
2. I *like* learning about science. I *sort of like* learning about science. I *sort of don't like* learning about science. I *don't like* learning about science.
3. Science is *easy* for me. Science is *sort of easy* for me. Science is *sort of hard* for me. Science is *hard* for me.
4. I *like* doing science. I *sort of like* doing science. I *sort of don't like* doing science. I *don't like* doing science.

The Cronbach Coefficient Alpha was .75, calculated on the attitude items of the prebroadcast questionnaire.

Attitudes toward science stereotypes. Prior to broadcast, students wrote a question they would ask a scientist to whom they were talking on the telephone. In the postbroadcast questionnaire, students again wrote a question they would ask a scientist on the telephone and also drew the scientist they imagined questioning.

Initial coding categories for the students' questions were determined through content analysis of 25 questionnaire answers from a pilot sample of fourth graders. Content analysis of 30 random prebroadcast questionnaires from the summative evaluation sample yielded an additional category (Request for action), which had not been mentioned by the pilot students. A student's question was coded as one of the eleven definition categories below:

- Attitude toward work ("Is being a scientist fun?")
- Content: Ancient Things ("How many bones do you find in a year?")
- Content: Chemistry ("What makes 409 and Windex and vinegar blow up?")
- Content: Earth & Space ("Is man able to live on Mars?")
- Content: Forces & Energy ("How does gravity work?")
- Content: Living Things ("What is in the human body?")
- Content: Technology ("When are flying cars coming?")
- Personal ("How did you become a scientist?")
- Process or Work of Science ("How do scientists find out all this information?")
- Request for Action ("Will you send me a kit?")
- Other ("Can girls be juniors?")

Inter-coder agreement on categories was 95% for 30 questionnaires drawn randomly from the sample.

The drawing procedure was included in the measures as a non-verbal assessment of students' images of scientists and their work, based on the Draw-A-Scientist Test (DAST) (Chambers, 1983; Newton & Newton, 1992). The DAST has been used typically to look at trends across age levels, and these studies have found that with age comes an increase in pictorial indicators of the stereotypical scientist (Chambers, 1983; Schibeci & Sorensen, 1983). Only one study has used the DAST to assess the effectiveness of an educational intervention, with mixed results in terms of support of the hypotheses (Mason, Kahle, & Gardner, 1991).

Although Chambers (1983) concluded that the DAST "may ultimately be more useful in the construction of hypotheses than in the testing of them" (p. 265), the test was included experimentally in this study to assess images of scientists after the radio intervention. Because media research indicates that audio versions of stories tend to stimulate more imaginative responses than video versions (Greenfield & Beagles-Roos, 1988), and because the *Kinetic City Super Crew* radio programs present conversations with real scientists, it was hoped that the DAST would capture some of the imaginative responses of listeners.

The DAST version in this study employed a variation on the traditional instructions: "Draw a quick picture of the scientist you imagined at the other end of the telephone. Draw a picture of that scientist working indoors or outdoors. Below the picture, explain what the scientist is doing in your picture. (Don't worry about how artistic you are. We know it's hard to draw people.)" The instruction to draw the scientist whom they were questioning on the phone was intended to increase the diversity of scientists and tasks depicted in the drawings and to

tie the drawing to the curiosities aroused by listening to the programs. Thus, one coding of the drawing was whether the picture matched in content the question that the student asked. For example, if a question was asked about volcanoes, did the picture show and describe someone studying volcanoes?

The DAST results were coded also for a subset of the coding attributes employed by Newton and Newton (1992) in evaluating drawings of 1,143 children in the United Kingdom. In the rare cases when more than one figure was drawn, the major figure was coded. Coded attributes of the drawn figure included gender; race (minority or not); and presence or absence of laboratory coat, glasses, and facial hair. Coded attributes of the scientist's task included workplace (indoors, outdoors, indefinite) and task content (ancient things, chemistry, earth and space, forces and energy, living things, technology, and non-science [e.g., sleeping]). Inter-coder agreement was 95% or above on the DAST attributes for 30 drawings chosen randomly from the sample.

RESULTS

Listening Behavior

When a treatment is uncontrolled, as the radio programs were, self-report is not sufficient to determine reliably who has been exposed to the treatment. Thus, a student was classified as having listened to a show only if his or her self-reported listening was confirmed by at least one of the following three criteria:

1. A parent signed a slip stating that the child had listened to all or part of a specific show; or
2. The student reported some information from a specific show in the open-ended questions (e.g., wrote that the water clock project did not work); or
3. The student indicated on the questionnaire that he or she did *not* listen to the two shows that were false listings.

Based on these stringent criteria, of the 253 students, 167 (66%) did not listen to any of the radio programs (Non-listeners of Any show), and 86 (34%) listened to one or more programs (Listeners of Any Show). Using this classification of the two groups, chi-square analyses were performed between groups on nominal variables for the series as a whole (as in Listeners of Any Show vs. Non-Listeners of Any Show) and for each program separately (as in Listeners of TIME vs. Non-listeners of TIME). Gender and ethnic group differences were assessed also with chi-square analyses. In the few instances where continuous variables were measured, t tests were used for analysis.

Table 1 presents the distribution by gender of Non-listeners of Any Show and Listeners of Any Show. Significantly more girls (59.3%) than boys (40.7%) listened to one or more programs: χ^2 (1) = 7.64, p = .006. Chi-square analyses of the remaining antecedent variables revealed no significant differences when Listeners of Any Show were compared to Non-listeners for ethnic status, attitudes toward science, reading science magazines, watching science TV shows, and for seven of the eight common at-home science activities listed. Listeners of Any Show were more likely (61.6%) than Non-listeners (44.9%) to report having done the eighth science activity of "examining things with a microscope or magnifying glass": χ^2 (1) = 5, 70, p = .02.

Table 1 ☐ Distribution of Non-listeners and Listeners of *Kinetic City Super Crew* Shows

Gender	*Non-Listeners*		*Listeners of One or More Shows*		*Total*	
	n	%	*n*	%	*n*	%
Female	67	40.1	51	59.3	118	46.6
Male	100	59.9	35	40.7	135	53.4
Total	167	66.0	86	34.0	253	100

Table 2 presents how many students listened to one, two, three, or four programs and how many listened to each of the individual four programs. The major reasons given for not listening to the programs on Tuesdays after school were, in order of most to least frequent, "sports activities," "too busy," "can't get/find station," and "didn't want to." Finally, of the 86 Listeners of Any Show, 40.5% reported that an adult listened to the program(s) with them.

Series Appeal

When presented with a four-point scale to rate the appeal of *Kinetic City Super Crew*, 58% of Listeners of Any Show said they "liked it," 37% said they "sort of liked it," 1% said they "sort of didn't like it," and 4% said they "didn't like it." A majority (88%) of the Listeners of Any Show wanted to hear more programs. Chi-square analyses revealed no gender or ethnic group differences in the appeal results.

Students' Perceived Learning

After the broadcast period, students were asked to list some of the new things they learned from listening to the programs. Specific information from one or more of the programs was recalled by 78% of the Listeners (e.g., "An elephant makes a sound so low that a human can't hear it but another elephant up to two miles away can hear it"; or "They used water clocks a long time ago.")

Of the 52 students who listened to TIME, 40% said they learned how to make water clocks or about water clocks (hands-on activity) and 21% reported learning different ways of telling time (informational segments). Of the 49 students who listened to SOUND, 37% said they learned about elephant sounds or how elephants communicate (mystery story), 8% learned about different pitched sounds from glasses of water (hands-on), and 6% reported learning how to make instruments (hands-on). Of the 31 students who listened to SEEDS, 22% said they learned how seeds travel (mystery; informational). Of the 30 students who listened to GARBAGE, 29% reported learning where waste water and trash goes (mystery) and 9% learned how to make time capsules (hands-on). Test results for these content areas are reported below.

Impact of Listening on Recall of Science Facts

After the broadcast period, students evaluated the truth of five statements for each of the four radio programs. Four of the five statements for each program were true, and answers were scored correct or incorrect. For each program, three statements were drawn directly from the program content, and two statements were related in content but not included in the program. A chi-square analysis was performed for each of the 20 statements (correct-incorrect vs. Listener-Non-listener). Of the twelve true-false statements drawn from the programs, five yielded statistically significant chi-square results (see Table 3). No chi-square analyses were significant for the eight statements that were related to the programs in content but not included in the programs.

As shown in Table 3, for each program, at least one of the three program facts was recalled correctly by significantly more Listeners than Non-listeners. Note, however, that only three of the five statements elicited correct

Table 2 ☐ Distribution by Show of Listeners (n = 86)

Listeners of	*n*	*%*	*Listeners of*	*n*	*%*
One show	44	51.2	TIME	52	20.6
Two shows	18	20.9	SOUND	49	19.4
Three shows	14	16.3	SEEDS	31	12.3
Four shows	10	11.6	GARBAGE	30	11.9

response rates beyond a 50% guessing rate. The timing of the postbroadcast test on the day after the GARBAGE broadcast might have affected the better recall for this program in particular. Within the listening group for each of these five statements, chi-square analyses revealed no differences between gender and ethnic subgroups.

Impact of Listening on Understanding of Program-Related Science Phenomena

To assess learning beyond simple recall, students were asked to draw and write about science phenomena described in the hands-on project or the science mystery story. To test understanding of the hands-on project in the TIME program, students were presented with a picture of a glass jar and a list of other objects that they would need to design a water clock. Students could score from 0 to 5 by including various components of the clock in their proper relationships (e.g., 1 point for a cup, right side up, in the jar mouth). Comparison of means indicated that Listeners of TIME (M = 1.38) scored significantly higher than Non-listeners (M = 0.13), $t(55) = 6.28$, $p < .001$. Among Listeners of TIME, t tests of mean scores revealed that females and males did not differ significantly nor did minority and non-minority groups.

Reflecting the hands-on project of the SOUND program, students were presented with three glasses labeled "high sound," "medium sound," and "low sound" and asked to draw lines to show where the water would be so that the glasses would make the different sounds when hit with a spoon. Students were scored "correct" if they drew lines in the correct height relationship. Chi-square analysis showed that no more Listeners of SOUND were correct than Non-listeners (67% vs. 54% correct, respectively).

To assess recall of the SEEDS hands-on project, students were to imagine that a random sample of dirt and water had been mixed in a clear plastic bag and left by the window for one week. Students were scored correct if they drew or wrote that seeds or plants would grow in the bag shown in the question. Significantly more Listeners of SEEDS were correct than Non-listeners (55% vs. 7%, respectively): χ^2 (1) = 52.65, $p < .001$. Among Listeners of SEEDS, gender and ethnic groups did not differ significantly in score, according to chi-square tests.

The score for drawing and/or describing the disposition of household sewage water (GARBAGE) could range from 0 to 8 by including eight components in their proper relationships (e.g., 1 point for fertilizer produced from water treatment plant). Listeners of GARBAGE (M = 1.57) did not score significantly higher than Non-listeners (M = 1.23).

Table 3 ☐ True-False Statements that Significantly More Listeners Answered Correctly than Non-Listeners

Program	*Statements (All were true and drawn from program.)*	% *Listeners Correct*	% *Non-Listeners Correct*	c^2
TIME	People can tell the time of day using a special metal called cesium.	42%	24%	5.72 *
SOUND	Elephants communicate with low pitched sounds that humans cannot hear.	63%	30%	16.98 ***
SEEDS	Seeds catch onto animals' fur and then are later rubbed off.	84%	60%	5.50 *
GARBAGE	Bacteria can make sewage smell better.	33%	16%	4.16 *
GARBAGE	Bacteria can make important vitamins.	69%	27%	11.65 ***

*$p < .05$ ***$p < .001$

Impact of Listening on Frequency and Kind of At-home Science Activities

In the postbroadcast questionnaire, students reported what science activities they had done at home in the previous two weeks. These answers were coded for number of activities listed and whether or not a student reported an activity that related to the content of the series. The mean number of science activities listed by Listeners of Any Show was .71 and was significantly higher than the mean of .49 reported by Non-Listeners of Any Show: $t(251) = 2.34$, $p = .02$.

Of the Listeners of Any Show, 17% described at least one activity that related to the content of the series, whereas 2% of the Non-Listeners of Any Show reported an activity that was coded as related to the series's content. Chi-square analysis indicated that significantly more Listeners than Non-listeners reported having performed an at-home activity related to the series's content: χ^2 (1) = 16.40, $p < .001$.

Students were asked also what kind of science activities they would like to do at home in the future. The mean number of future science activities described by Listeners of Any Show was 1.5 and was not significantly higher than the mean of 1.3 reported by Non-listeners of Any Show. Only 7% of Listeners and 2% of Non-listeners described a future activity that was coded as related to the series's content, and chi-square analysis indicated no significant difference between the groups on this variable.

In addition to the question about general activities asked of all students, Listeners in particular were asked whether they had done any of the science experiments or projects as suggested in the radio programs. Of the 86 Listeners, 40% described one or more program activities, and there were no significant differences between gender and ethnic subgroups. Some of the radio-inspired projects were more successful than others: "My water clock backfired. It made a mess and only worked for ¼ of a minute" [TIME]. "I did the water one and it was neat. I could play Mary had a little lamb" [SOUND]. "I put dirt in the bag and nothing happened" [SEEDS]. "I did the time capsule. I wrote about what teacher I had, who I liked and about dance. And I won't open it for 15 years" [GARBAGE].

Looking at the activity results for each program individually, 29% of TIME Listeners tried making the water clock, 27% of SOUND Listeners described making a water glass or rubber band musical instrument, 19% of SEEDS Listeners collected a dirt sample to observe growth, and 10% of GARBAGE listeners made a time capsule.

Impact of Listening on Student Definition of Science

Before and after the broadcast period, students were asked to write down what they think science is. Pre- and postanswers were coded dichotomously according to whether or not a student mentioned each of eight categories (Experiments, Inventing, Knowledge, Learning, People, Process, Tools, Other). The McNemar chi-square test for the significance of changes was applied to each category for the pre- and postresponses of Listeners and Non-Listeners. None of the eight tests for either group was significant.

Impact of Listening on Attitudes Toward Science and Science Stereotypes

Prior to broadcast, the fourth graders' reported attitudes toward science were very positive. When presented with a four-point response scale, more than 90% of the 253 students agreed with either the positive ("like," "fun," "easy") or "sort of" positive attitude statements, as follows: "I like learning about science" (53%); "I sort of like learning about science" (40%); "Science is fun" (57%); "Science is sort of fun" (35%); "I like doing science" (64%); "I sort of like doing science" (27%); "Science is easy for me" (46%); "Science is sort of easy for me" (45%).

An analysis of covariance on each of the four variables was performed on the pre-post gain scores, controlling for differences on the prebroadcast questionnaires. No changes in attitude were found based on whether a student had listened to a program or not.

Both before and after the broadcast period, each student wrote a question to ask a scientist on the telephone. (Eleven students did not complete this question.) Neither Listeners' nor Non-listeners' questions mentioned the series content, either specifically or generally. Student questions were coded according to one of eleven exclusive categories, as shown in Table 4. The large number of earth and space content questions apparently reflect the fact that earth sciences were being covered in the fourth-grade classroom curriculum during the broadcast period; the radio shows did not touch on this topic.

To test whether Listeners and Non-listeners differed with respect to their eleven categories of questions, chi-square analyses were performed for the prebroadcast data and postbroadcast data. No results were significant.

In the postbroadcast questionnaire, after writing their questions for scientists, students were to draw their imagined scientists at work and explain their drawings. Only 21% of students drew scientists at tasks related to their questions. Most of the postbroadcast questions dealt with earth and space sciences (25%), but only 14% of the drawings did. Most of the drawings depicted chemistry-type tasks (52%), but only 7% of the questions did. Most drawings showed white (96%) males (51%) indoors (64%) at chemistry-type tasks (52%). It was hoped that exposure to scientists and a variety of science fields on the radio series would be reflected in the non-verbal Draw-A-Scientist Test. Only *three* listener drawings were related to program content, and chi-square analyses revealed no significant differences comparing Listeners of Any Show to Non-Listeners of Any Show for each of the seven attributes coded for the drawings.

DISCUSSION

About one-third of the fourth graders listened to one or more radio programs in the *Kinetic City Super Crew* series of four. This audience size is comparable to what has been found for new *television* programs for this age group. For example, an evaluation of a 13-part PBS weekly series called *Feeling Free* encouraged home viewing with teacher reminders. One-third of the surveyed audience of fourth through sixth graders watched one or more programs (Johnston, Ettema, & Davidson, 1980). A daily series can elicit more viewing; for example, the first season of the PBS series, *The Electric Company*, was viewed at home by 59% of fourth graders, whose teachers had encouraged them to watch (Ball & Bogatz, 1973).

In the specific case of this radio series, sev-

Table 4 ☐ Categories of Questions Asked of Scientist

	Prebroadcast		*Postbroadcast*	
Question Category	*% Listeners n = 86*	*% Non-Listeners n = 156*	*% Listeners n = 86*	*% Non-Listeners n = 156*
Attitude toward work	19.8	12.8	18.6	18.8
Content: Ancient Things	5.8	6.4	2.3	3.0
Content: Chemistry	5.8	9.6	3.5	9.1
Content: Earth & Space	22.1	17.3	27.9	23.0
Content: Force & Energy	5.8	3.8	1.2	6.1
Content: Living Things	5.8	6.4	4.7	6.1
Content: Technology	2.3	5.1	2.3	4.8
Personal	15.1	11.0	10.5	9.7
Process or Work of Science	15.1	22.4	24.4	12.7
Request for Action	2.3	3.2	2.3	3.6
Other	0	1.9	2.3	3.0

eral factors worked against obtaining a larger audience. First, fourth graders do not have a steady habit of listening to the radio (Giovannoni, 1992) as they do television. Second, the children's radio station that carried the series was only one month old and had not yet developed a large listening audience. Third, the series itself was new within the station's programming, and finally, the series was broadcast weekly in a spring afternoon time slot during which children are typically outside or at other after-school activities. Solving the problem of attracting the target audience will be one of the largest barriers to overcome for *Kinetic City Super Crew* to be successful in a full-blown series.

One might expect the radio series to attract only those who were most interested and active in science, but that was not the case. Listeners of the radio series did not differ significantly from Non-listeners for most of the background variables measured, including attitudes toward science, science reading and science television viewing habits, and participation in seven of eight common at-home science activities. Listeners were significantly more likely than Non-Listeners to have reported doing the at-home science activity of "examining things with a microscope or magnifying glass." More importantly, significantly more girls listened to the programs than boys, which is good news because a goal of the series is to reach out to audiences who are underrepresented in science.

The finding that the self-selected comparison groups of Listeners and Non-listeners did not differ in prebroadcast science interests, habits and attitudes permits one to feel more comfortable about assuming that exposure to the radio series influenced differences in outcome variables. Even so, the conclusions drawn below must be qualified by the fact that the sample was not random and not all extraneous variables were controlled; for example, no measure of general science ability was included that might distinguish between Listeners and Non-Listeners.

The *Kinetic City Super Crew* series was "liked" or "sort of liked" by 95% of the listening audience, but the critical question is whether the series met its three major goals. First, did the series significantly increase listeners' knowledge and understanding of selected phenomena and science concepts? In response to an open-ended question, three-quarters of the Listeners could recall information that they learned from the series, for example, how to make a water clock or how elephants communicate. When program facts were tested in a modified true-false format, significantly more Listeners than Non-listeners recalled five of twelve program facts correctly; yet overall performance on the true-false items was not very high. When understanding of science phenomena was tested, two of four program questions were answered correctly by significantly more Listeners than Non-listeners. Neither gender nor ethnic background was a factor in these results. Thus, the series appears moderately successful at communicating its information to listeners in the home setting. Significant recall of information for the TIME program occurred at least three weeks after broadcast, indicating the potential of an informal medium like radio to have long-term effects on children's knowledge.

Second, did the series significantly engage children in active, hands-on science learning outside of school? Students were asked to describe what science activities they had done at home in the last two weeks, that is, the final two weeks of the broadcast period. Listeners reported doing significantly more science activities at home than Non-listeners and significantly more activities that drew upon the radio content. One could argue that this result was not related to the radio series, if the self-selected Listeners were more science-oriented than Non-listeners. However, comparison of Listeners and Non-listeners on prebroadcast science background variables revealed only the one significant difference summarized above. In addition, 40% of Listeners could describe the results of performing one or more of the experiments or projects as suggested in the radio programs. These findings imply that the series encourages students to carry out science activities directly related to the program and that the series may encourage other home experimentation, not related to the programs' contents. This conclusion must be tempered by recognition that other unmeasured background

variables, like science ability, may be operating in these findings.

Finally, did the series foster positive attitudes toward science, countering stereotypes of science and scientists? The findings did not indicate any influence of the radio series on attitudes or stereotypes. This result was not unexpected. The radio series comprised a total of two hours spread over four weeks, and half of the Listeners reported exposure to only one half-hour program. Few attitudes change with such limited treatment.

In addition, the attitude measures used may not have been appropriately sensitive to the effects of the series. Prior to broadcast, the students already indicated very positive attitudes toward science, so the attitude statements could not register much change as a result of listening. Further, despite modifications in the Draw-A-Scientist Test instructions, students apparently responded by presenting an "icon" of a scientist—that is, an image that all will recognize as a "scientist"—rather than presenting a scientist that reflects their own views and attitudes. Newton and Newton (1992), in their study of drawings by United Kingdom children, questioned whether the figure "is a reflection of a concept, like 'scientist,' or is it only a symbol for a scientist, like those pictures of teachers which still show them with caps, gowns and canes? As an absolute instrument, it is unclear yet if the test has more than a potential to indicate the level of awareness of aspects of the popular image of science" (p. 340). Experience with the instrument in this study does not support the DAST as a valid measure of attitude change.

Listeners learned from all three components of the program format: the science mystery story, the hands-on project, and informational segments. Students liked the programs, listened through the whole half-hour period (with commercials!), and wanted to hear more programs. These youngsters were able to follow an adventure story in a magazine format and comprehend and recall science information and project instructions using the auditory mode alone. Thus, as limited in scope as this causal-comparative evaluation was, the results indicate positive potential for using radio to expose children to science at an early age. □

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