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FEEDBACK SCORING SYSTEMS FOR REUSABLE KINDERGARTEN WORKBOOKS.

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THE DEVELOPMENT OF ECONOMICAL FEEDBACK SCORING SYSTEMS FOR REUSABLE KINDERGARTEN WORKBOOKS IS DESCRIBED. THREE PROTOTYPE SYSTEMS WERE DEVELOPED--(1) A METAL FOIL ACTIVATING AN ELECTRICAL PROBE, (2) A METAL FOIL REACTING WITH A MAGNETIC PROBE, AND (3) INVISIBLE FLUORESCENT INK REVEALED BY THE APPLICATION OF LONGWAVE ULTRAVIOLET LIGHT. (MS)

FEEDBACK SCORING SYSTEMS
FOR REUSABLE KINDERGARTEN WORKBOOKS

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A Report
Submitted to

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ABSTRACT

This report describes the development of economical feedback scoring systems for reusable kindergarten workbooks. The development was conducted in three stages: (1) a non-critical idea-generating phase, (2) an idea-analysis phase, and (3) a prototype development phase. Three prototype systems were prepared: (1) a metal foil activating an electrical (light-bulb) probe, (2) a metal foil reacting with a magnetic probe, and (3) invisible fluorescent ink revealed by the application of longwave ultraviolet light.

The invisible fluorescent ink system is the most satisfactory in terms of flexibility of page design and marginal unit costs: whereas the electrical and magnetic systems require the mechanical application of metal foils (satisfactory inks could not be developed), fluorescent inks can be applied by conventional printing and writing techniques. Further, printing with black ink and invisible ink costs only 25% more than a two-pass printing with black ink alone; it is doubtful that metal foils can be applied mechanically as cheaply. A suitable longwave ultraviolet source is expected to cost of the order of a couple of dollars when perfected for the purpose and mass-produced. Bulb manufacturers should be consulted in this regard.

The ultraviolet light system works best in subdued light. To compensate for low-level ambient illumination, we suggest that an ordinary light be incorporated with the ultraviolet probe. The ordinary light would be dimmed or doused when it is desired to check an answer with the ultraviolet probe.

INTRODUCTION

The project's objective is the development of a safe, economical feedback scoring system for reusable kindergarten workbooks. The workbooks will be used to provide immediate item-by-item feedback to the student as he progresses through a learning program. The student cannot be expected to read. The workbooks will be reused, so nothing done by one student should reveal the right answer to subsequent students. Non-reversible color indicators activated by moisture applied with a felt or fiber pen have been used successfully, and any reversible technique proposed must be less expensive in the long run than the use-once, non-reversible process now available.

PROCEDURE

The project was conducted in three phases: (1) a non-critical idea-generating phase, (2) an idea-analysis phase, and (3) a development phase culminating in several prototype systems.

A brainstorming session was used to generate a pool of ideas which could be expanded and/or analyzed to obtain potentially satisfactory solutions. The brainstorming was conducted by approximately twenty undergraduate students and two professors. Because the goal of this phase was merely to unearth a large variety of potential techniques, no critical analysis was made during this session and no ideas were discarded. The result was a long list of various approaches given in Appendix I.

The project then moved into the second stage. Ideas from the previous stage were grouped according to general categories and ideas that were non-reversible or non-reusable were dropped from the list. Surviving ideas from stage one were classified according to what the kindergartener would have to do to the workbook to indicate his answer (stimulus) and what the workbook would have to do to tell the student if his answer were correct (response). A two-dimensional matrix was used to plot stimulus elements vs. response elements as shown in Appendix II. Response elements were further categorized according to whether or not some sort of regenerative action would be required to restore the workbook to its original condition before reuse. Non-regenerative schemes are generally more straightforward. The entire matrix was reviewed, and three combinations were considered worth developing in prototype: (1) a low wattage electrical (light-bulb) probe, (2) a magnetic probe, and (3) sympathetic or disappearing ink. Each is described in turn.

The low wattage electrical probe (Fig. 1) is very similar to a penlight. Instead of having a button switch on the end of the penlight to light the bulb, the button is replaced with two probes to be placed on an element on the workbook page. If the element forms a closed circuit with the probes, the bulb lights; if the workbook element forms an open circuit,

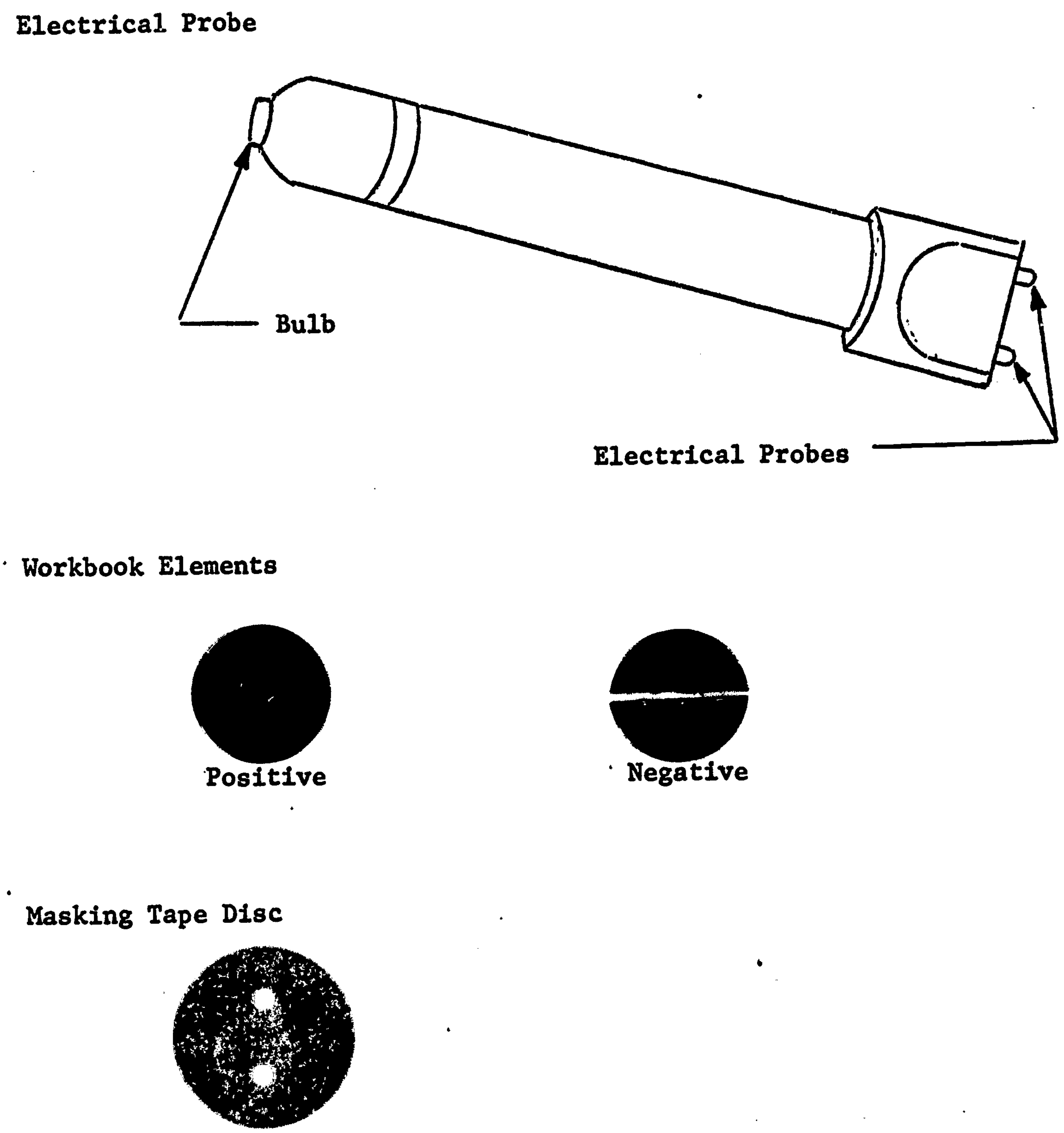


FIGURE 1

Electrical Probe and Workbook Elements
for a Low Wattage Electrical Feedback System

the bulb does not light. One kind of element is used for positive feedback (bulb lighted) and another for negative feedback (bulb unlighted).

The most convenient type of element to use from the standpoint of book preparation would be a printed strip of conducting ink for positive feedback (closed circuit) and an identically appearing printed strip of non-conducting ink for negative feedback (open circuit). Unfortunately, a printable conducting ink with a satisfactory conductivity could not be found or made, and this idea for the element was abandoned. As an alternative, metal discs disguised with tape were developed as workbook elements. Two dies were made to punch out element discs from metal foil. As shown in Figure 1, the element for positive feedback is a complete foil disc and the one for negative feedback has a strip cut out of the middle. Both kinds are covered with masking tape discs with appropriate holes to expose a portion of the foils to the probe. (Fig. 1) It is desired to have as thin a foil element as possible so that the split cannot be detected by running a finger over the foil-masking tape assembly. For the prototype, heavy-duty aluminum foil was used for the elements; regular aluminum foil was discarded because the probes tore the foil easily. The discs could be applied either in mass-production or individually by the teacher for a special project. The retail unit cost of the probe is estimated at 75¢ to a dollar. Occasionally replacing the bulbs and batteries in the probe is the only maintenance anticipated.

The magnetic probe consists of a small cylindrical magnet in a handle of roughly the same size and shape as the electrical probe (Fig. 2). The workbook element is a spot of magnetic material for the positive feedback, and an identically appearing spot of non-magnetic material for negative feedback. The magnet would attract and raise the page when placed over the magnetic spot. Printable magnetic ink would have been the best workbook element.

Commercial magnetic inks (as used for printing checks, etc.) were not strong enough to give satisfactory positive responses. Experiments were conducted in vain to produce a satisfactory magnetic ink. Regular black letterpress ink (#6-74-1 L.P. Job Ebony Black from Walter W. Lawrence) and commercial magnetic ink (o/s Rotary Magnetic Black #24-006 from Walter W. Lawrence) were then doped with iron powder or cobalt powder. Using an ink-magnetic powder ratio so small that there was hardly enough ink to hold the powder (when dry the powder could be brushed off), the doped ink still did not produce satisfactory results. Thus a foil disc system similar to that used with the electrical probe was developed.

Magnetic foil provided positive feedback (nickel was used due to immediate availability, but iron foil would probably be cheaper) and a non-magnetic foil provided negative feedback (aluminum discs identical to those in the electrical system were used). The foil discs were secured to the page with masking tape discs as in the electrical probe system, except that these tape discs were left unpunched. It may be possible to apply a dot of magnetic metal powder in a resin substance instead of using a metal disc, but this scheme would still not be printable and no other

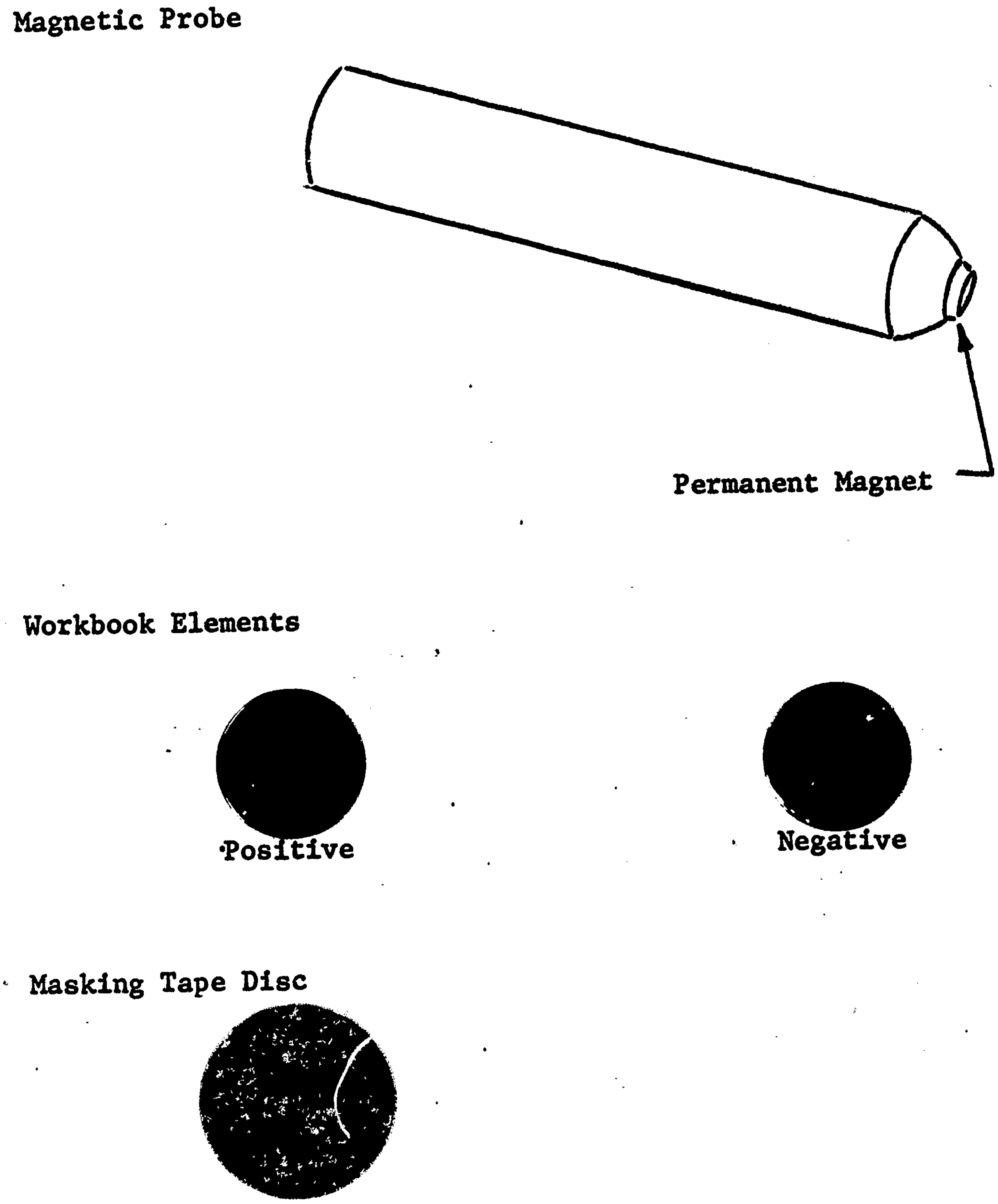


FIGURE 2

Magnetic Probe and Workbook Elements
for a Magnetic Feedback System

advantages in this approach are apparent. Response definition with the magnetic element is very sensitive to the way the student uses the probe, and this is considered a serious drawback. The magnetic system has one advantage over the electrical system: it does not have bulbs or batteries to fail.

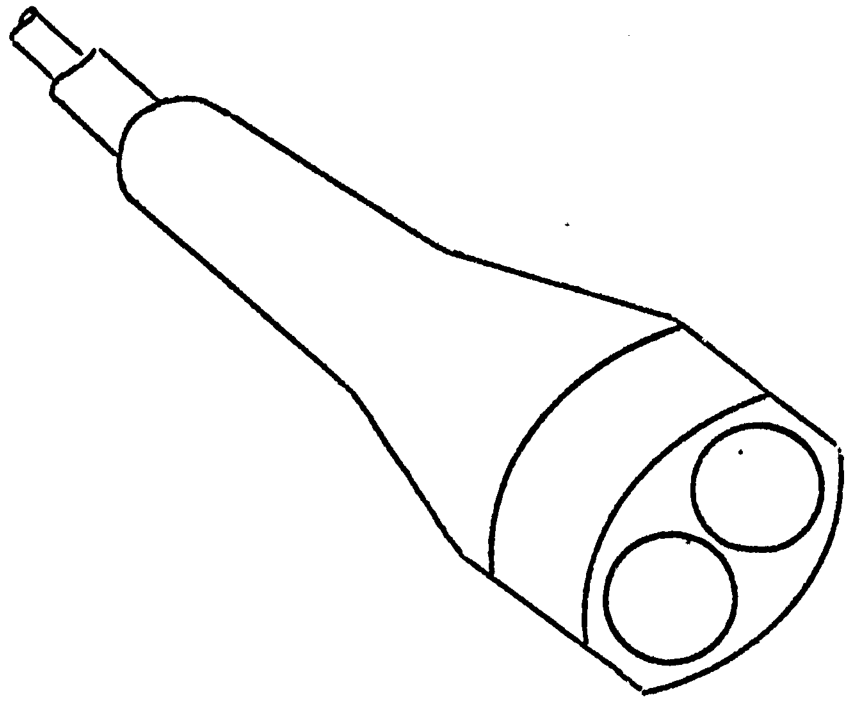
Extensive work with various kinds of sympathetic inks resulted in only one workable system. Two references (1, 2) provided a list of several kinds of ink which could be revealed by the application of various chemicals and made to disappear with other chemicals. One system tried was a water-responsive ink made of linseed oil (1 part), ammonia water (20 parts), and distilled water (100 parts). The image appears when the page is moistened with water, and disappears when the page is allowed to dry. This system was moderately successful, but it was not further explored because it sooner or later washes off the page. The second sympathetic ink tried was a solution of salicylic acid. The writing is made to appear by washing the area with a neutral solution of ferro-perchlorate, and regeneration takes place with the application of hydrochloric acid. It was concluded that any ink revealed by chemical washing has limited repeatability (a total of fifteen cycles was deemed a satisfactory lifetime). Even if the ink itself were not washed away after fifteen cycles, most paper would show noticeable deterioration around the correct answer.

A search for inks revealed by other than wet-chemical means led to the development of a successful prototype system using invisible fluorescent inks revealed by longwave ultraviolet radiation. Printing, writing, and stamp pad inks are available from UltraViolet Products, Inc., San Gabriel, California, and samples of their products are shown in Appendices V and VII. Invisible crayons and pencils are also available, and they are shown in Appendix VI.

Two types of answering schemes were tried with fluorescent inks. One had detail added to the correct picture, and the other had traditional smiles ("yes") and frowns ("no") attached to the appropriate pictures. Invisible inks offer two alternatives in page preparation: By using offset or letterpress printing, books can conveniently be mass-produced. On the other hand, by using a writing ink, a stamp pad, crayons, or pencils, the teacher can easily produce sample pages one at a time.

The reader will note that the fluorescent images stand out most clearly when the ambient illumination is subdued. This suggests that the lamp switch design should incorporate a means for subduing the general illumination when the ultraviolet light is on. Or alternatively, a fixture holding both an ultraviolet light and a conventional light can be arranged to provide whichever type of light is required: for general scanning, the conventional light would be lit, and for checking answer blocks, the conventional light would be doused and the ultraviolet source lit. A possible fixture design is shown in Figure 3.

Ultra-Violet Radiation Source



Circuit Diagram for Ballasting

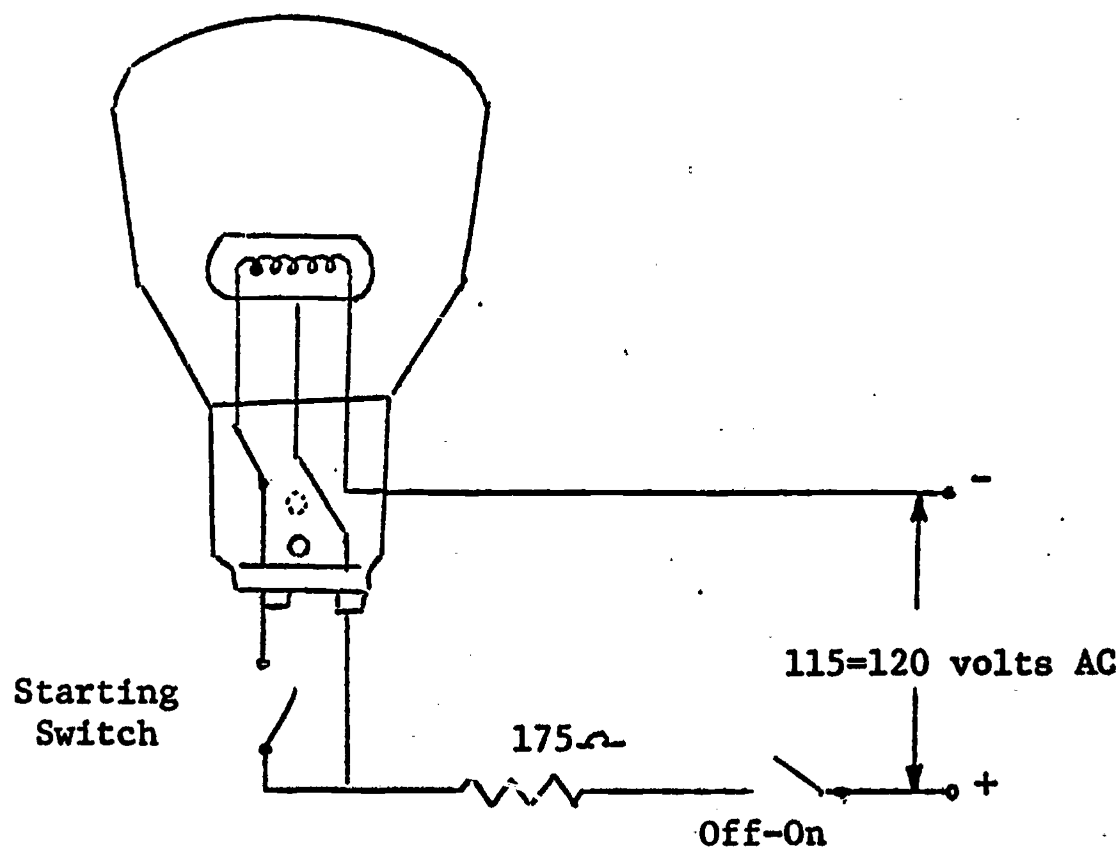


FIGURE 3

Long-wave Ultraviolet Probe for use
with Fluorescent Inks and Crayons in a Feedback System

For prototype testing a commercial source (Mineralight "NH" Multi-band Lamp, UltraViolet Products) and a homemade lamp incorporating a General Electric MF 5000 bulb were used. While they worked satisfactorily, they incorporate fair-sized bulbs and are probably too bulky for kindergarteners to handle comfortably. Since smaller ultraviolet bulbs than the ones used in these sources are apparently not available and must be custom made, it is suggested that bulb manufacturers be consulted in preparing the desired overall fixture.

The cost of printing with invisible ink seems reasonable. A two-pass printing operation (one black ink printing plus one invisible ink printing) would cost about 25% more than a two-pass printing in black ink alone. (Invisible ink is $19.50 per pound versus $2.50 per pound for black ink, and ink is about 8% of the cost in a normal printing operation.) The cost of a suitable light source is difficult to estimate. Providing manufacturing costs for the smaller bulb in the quantities desired are comparable to the costs for the General Electric MF 5000, we estimate a total cost for bulbs, holder, ballast, etc. would be of the order of a couple of dollars. This implies, of course, that middleman costs can be eliminated, a reasonable assumption we feel if the items are ordered in manufacturing lots for distribution to schools.

CONCLUSION AND RECOMMENDATIONS

The study produced three workable prototypes, each with relative strengths and weaknesses. The electrical (light-bulb) probe has perhaps the most positive stimulus; when the child gets a correct answer his whole face will be illuminated. But this system is perhaps the most expensive in the long run since batteries must be replaced periodically and because of the mechanical process required to apply the discs in large quantities. The magnetic system also requires a mechanical application of discs, but it does not have any parts to be replaced. However, the magnetic system's response is the least definite, and this is considered a significant drawback. In terms of production, the fluorescent ink system would be the best. Mass production can be offset or letterpress printed, and invisible fluorescent writing inks, pencils, and crayons are available for teacher application. The initial cost of a couple of dollars for the ultraviolet source is the least attractive part of this system.

In summary, the electrical system and the magnetic probe are much less flexible and not necessarily less expensive on an overall basis than an invisible ink-ultraviolet light system. We recommend that the invisible fluorescent ink-ultraviolet light system be tested in depth with kindergarteners, and that the other alternatives be considered reserves. This of course implies development of a suitable ultraviolet source by bulb manufacturers.

APPENDIX I

ITEMS AND PHRASES LISTED IN THE BRAIN STORMING SESSION

Computer-programmed text
Teaching machine - template
Magnetic tape
Magic slate plus color keys
Electrical matrix
Skinner box
Moisture sensitive paper
Multiple choice buttons (magnetic - electrical - spring)
Pneumatic amplifiers
Skinner box with sound effects
Polarized light
Color test with liquids
Chemical reactions
Disposal
Peek-a-boo - light templates
Compare answer -- picture, word
Flash cards - film projector
Hidden keyholes
Address book -- edge tabs
Luminescent material
Talking answer book
Burn if wrong
Heat gun
Ultraviolet light
Amusement park -- photoelectric
Slot machine
Water sensitive - evaporation reverses
Plastic bowling sheet or other nonadhering surface
Light sensitive glass

ITEMS AND PHRASES (Cont'd)

Template over squeeze bottle

Invisible ink - light sensitive

Magnetic material in plastic sheet

Plastic polarizer

Green cue under gree plastic

Split pages -- twin books

Polarized magnifying glass

Tabs

Automatic regeneration of scratch

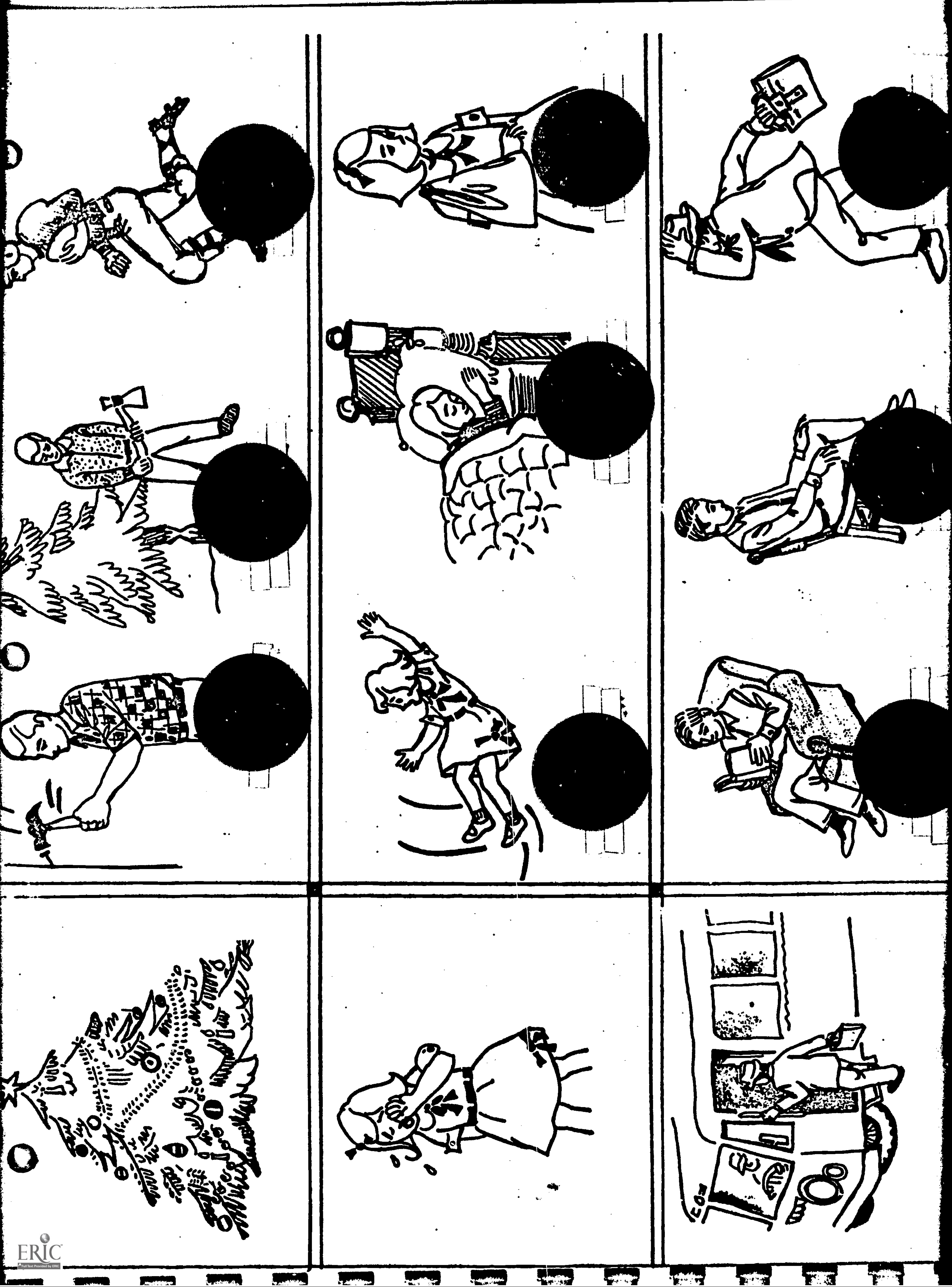
APPENDIX II

A MATRIX OF RESPONSE ELEMENTS VERSUS STIMULUS ELEMENTS

RESPONSE / STIMULUS	Color changes	Color or symbol revealed	Bulb lights	Sound produced	Push-pull experienced	Change of state
APPLY FORCE Mechanical						
Magnetic						
Electrical						
APPLY ENERGY Heat						
Light						
Sound						
APPLY MATERIALS Water						
Other Chemicals						

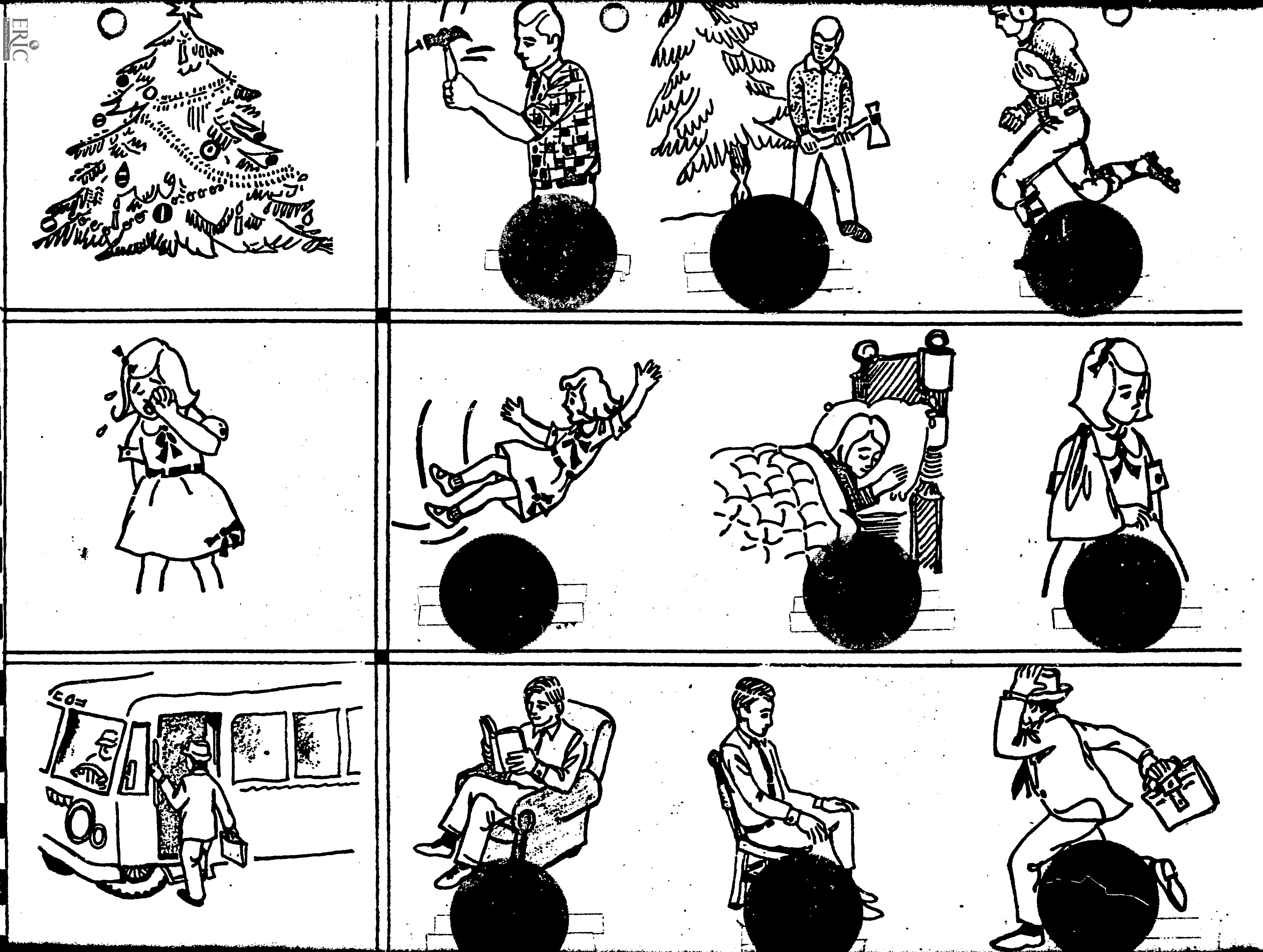
APPENDIX III

ELECTRICAL SYSTEM WORKBOOK PAGE



APPENDIX IV

MAGNETIC SYSTEM WORKBOOK PAGE

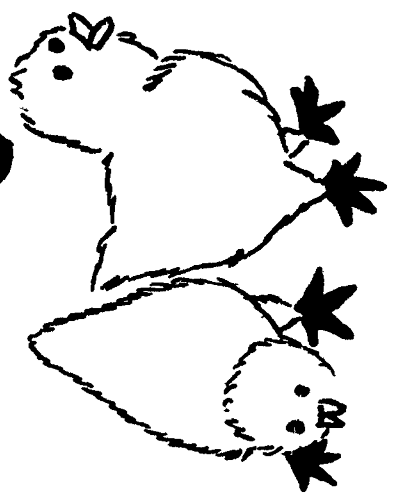
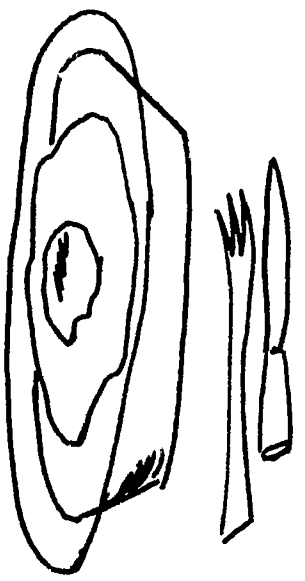


APPENDIX V

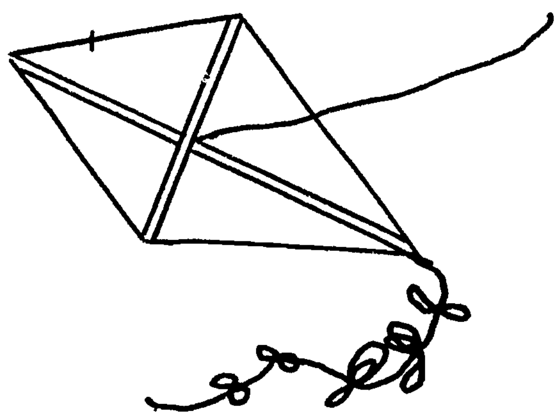
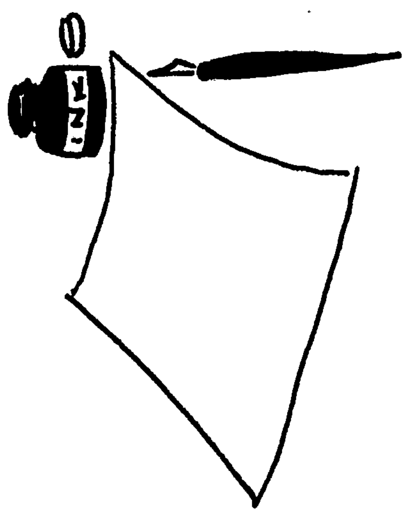
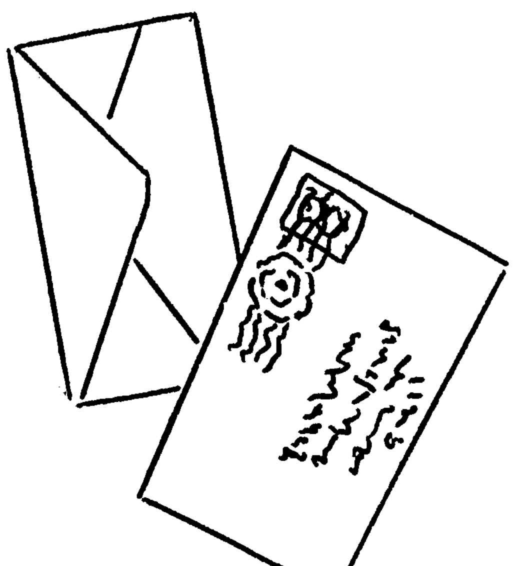
SAMPLES OF PAGES LITHOGRAPHED WITH INVISIBLE INK

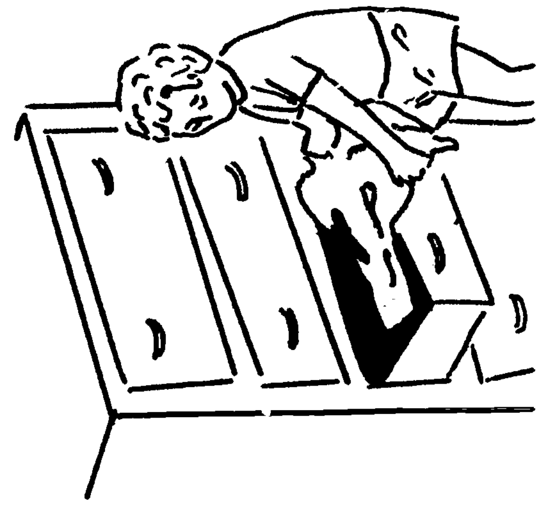
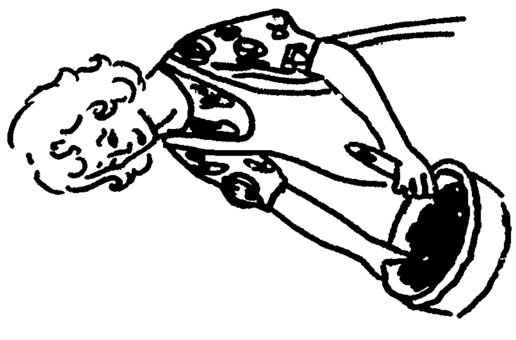
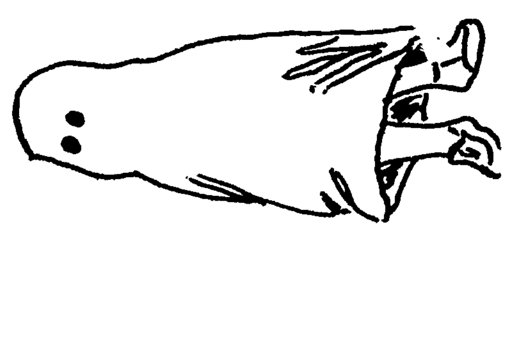
APPENDIX VI

WORKBOOK PAGES WITH INVISIBLE INK, PENCIL, AND CRAYONS

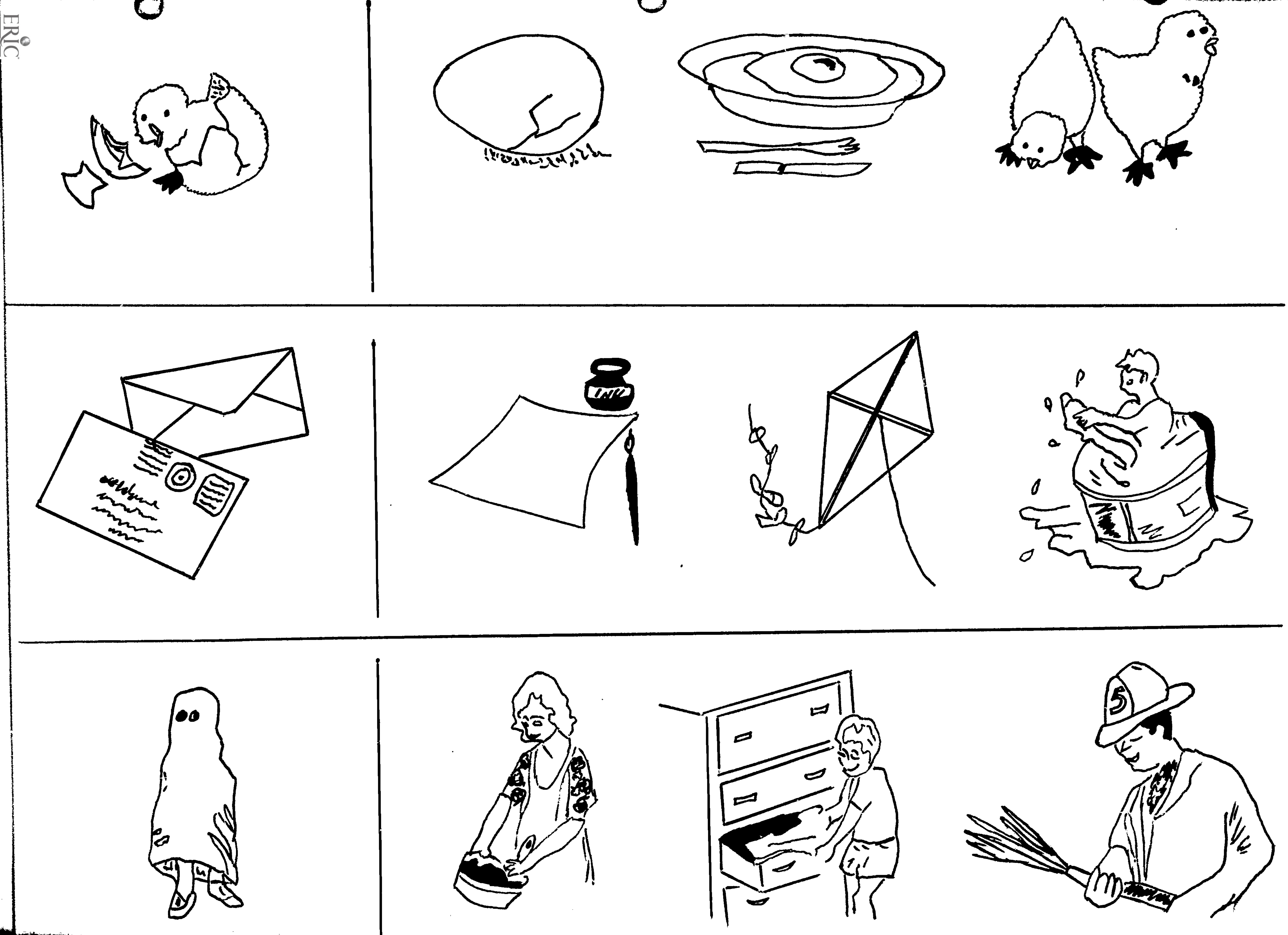


APPENDIX VII

WORKBOOK PAGES WITH INVISIBLE FLUORESCENT WRITING INK



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