Scanner Art and Links to Physics

David Russell
Sekolah Global Jaya, Jakarta, Indonesia
d.russell@physics.org

Abstract

A photocopier or scanner can be used to produce not only the standard motion graphs of physics, but a variety of other graphs that resemble gravitational and electrical fields. This article presents a starting point for exploring scanner graphics, which brings together investigation in art and design, physics, mathematics, and information technology.

Introduction

My initial aim in experimenting with photocopiers and scanners was to generate graphs for the study of motion (kinematics). It seemed that the scanning beam would provide a ready-made time base, the horizontal axis for displacement-time graphs (Figure 1). Taking the direction of scan as the positive direction of the X-axis, and moving a horizontal line drawn on an A3 sheet up and down at right-angles to the direction of scan, I could produce all the standard displacement-time graphs. These included curves for constant velocity and constant acceleration (both positive and negative), as well as simple harmonic motion. A scanner gives results with higher definition than a photocopier.

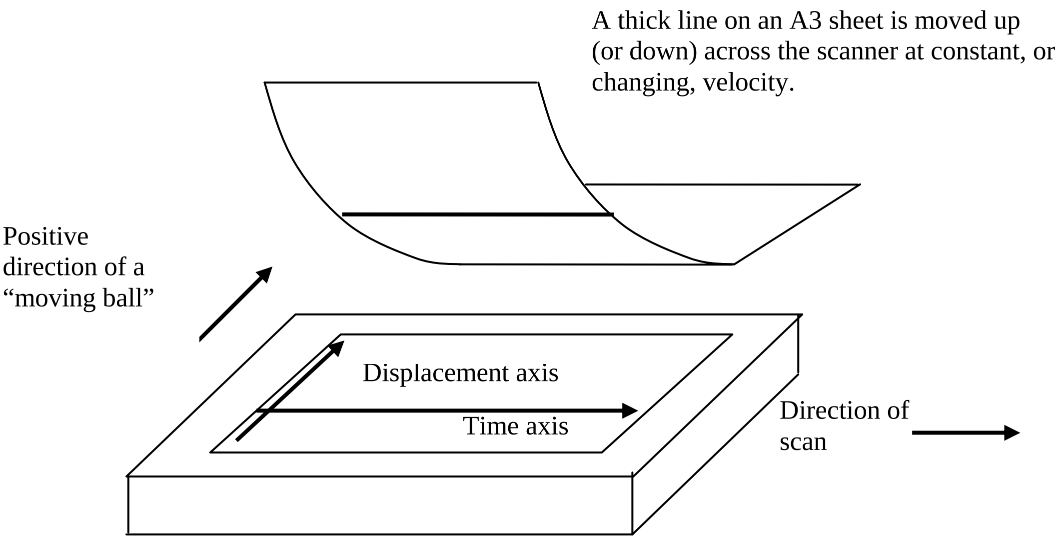


Figure 1. Scanner with lid removed. A "moving ball" is represented by an extended line. The "ball" is the point where the scanner crosses the drawn line at any instant.

Scanner Art

That may have been the end of my efforts, but out of curiosity I tried rotating the line about its center and, depending on the rate of rotation, obtained a series of interesting curves. Then, I tried rotating a pattern of intersecting lines, as follows. I drew a black-on-white wheel design (Figure 2, scan 1) that filled the width of an A4 sheet of light card. I taped an up-turned drawing pin to the centre of the scanner glass and centered the wheel face down on the pin, enabling me to rotate the wheel using one finger touching the periphery. The area outside the circle was masked in white, although this was not necessary. To make the other designs shown in Figure 2, I rotated the wheel anticlockwise at constant angular velocity, using progressively faster speeds for scans 2 through 6. The scanning direction was from top to bottom.

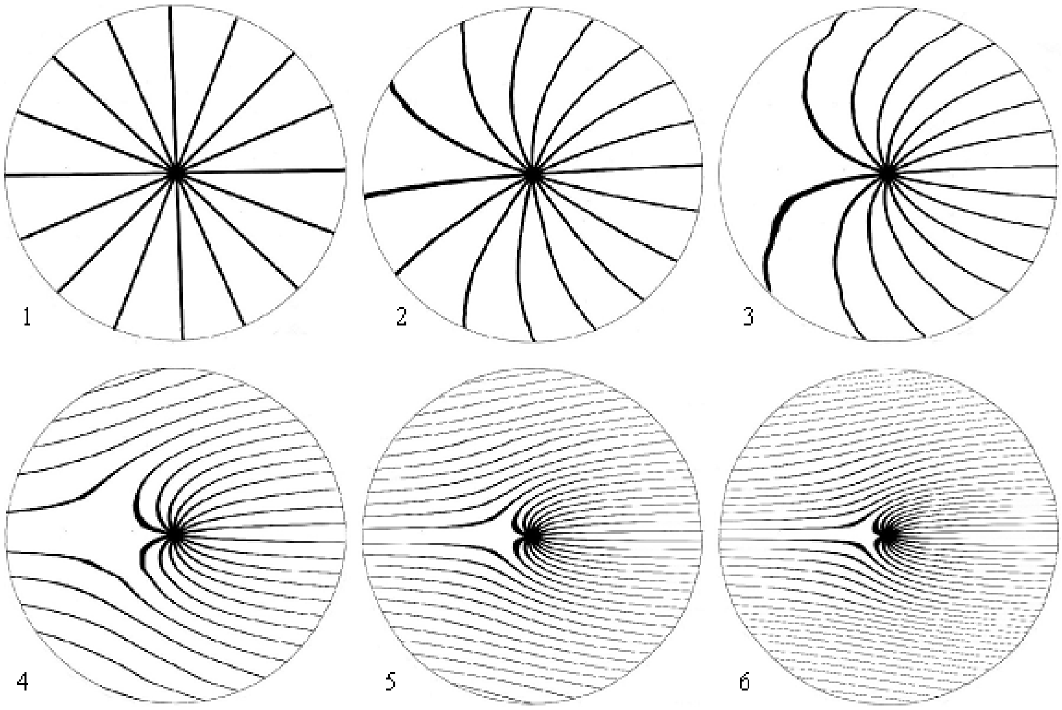


Figure 2. The results of scanning a spoked-wheel design, shown stationary in scan 1, and rotated with progressively greater angular velocities through scans 2 to 6. In scan 6, the wheel was rotated anticlockwise by finger almost three times during the period of completing the scan, and the scan passed from top to bottom.

It took an hour to make a more sophisticated wheel mechanism (Figure 3) that sat astride my scanner. A long screw served as a handle, and with a little practice it was possible to rotate the wheel with smooth constant velocity (or regular oscillations) by hand.

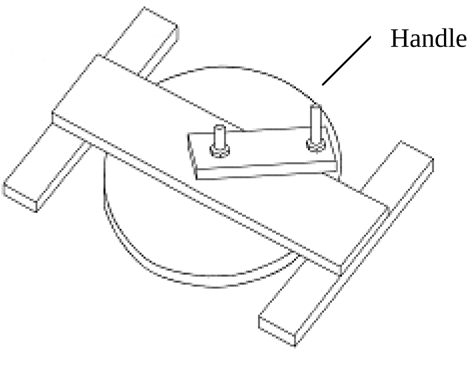


Figure 3. This rotating wheel and frame can be made of any rigid board or plastic, glue, counter-sunk screws, nuts, and washers. The frame sits astride the scanner glass. The 18-cm diameter wheel (with white underside) is rotated by hand. Drawings of lines, shapes, portraits, and so forth are loosely attached to the underside with a few dabs of a glue stick.

Attributing Meanings From Physics

The curious symmetrical patterns of Figure 2 reminded me of designs I had seen in physics texts. Could the patterns represent physical phenomena quite removed from their wheel-and-scanner origins? Based on the principle “Things that *do* the same *are* the same” (for example, if a magnet attracts both iron and an unknown solid, then the unknown must also be iron), if the scanner art mimics a physics graph, I asked myself: Why are they the same? Does one mathematically model the other? How deeply does the similarity extend? Are there broader lessons to be learned from the similarities?

After some thought, it appeared to me that scans 4 to 6 of Figure 2 model characteristics of two physical situations. The first is the gravitational field associated with a two-body system such as the Earth and Moon, represented in part by the conventional two-dimensional gravitational field diagram of Figure 4. The field shape depends on one mass being much less than the other.

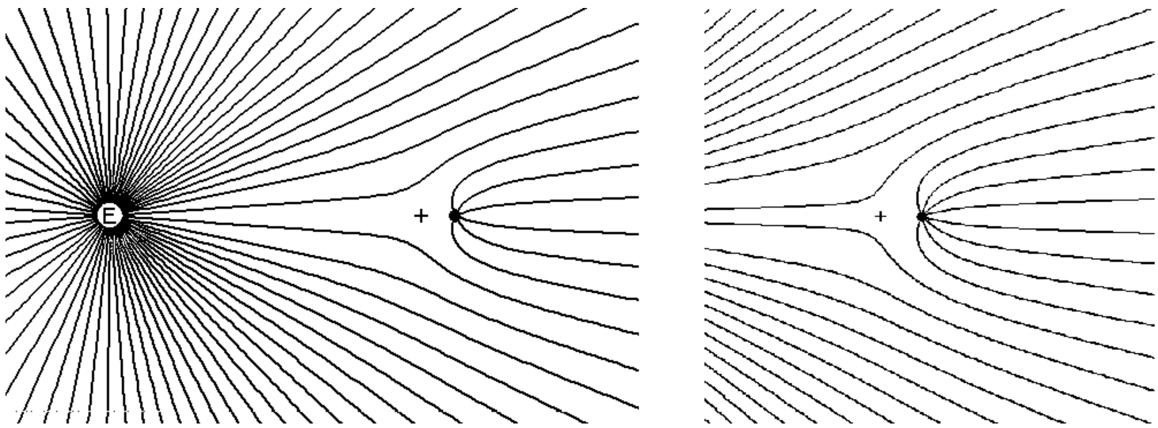


Figure 4. Two-dimensional gravitational field diagram of the Earth-Moon system. Notice the similarity between the enlarged section on the right, and Figure 2 scan 4. The neutral point in the field is marked with a cross.

The second application is the electric field surrounding two unequal electric charges. A typical field diagram (without vector arrows) appears in Figure 5.

While writing this article, a friend saw in Figure 2, scans 2 and 3, a Doppler-shift connection, though he was not sure as to why. Perhaps it was because in Figure 2, scan 2, as viewed from the top, the lines in the left semicircle are spread further apart than in the right semicircle. The fewer lines on the left may represent sound waves received by a person facing a receding sound source (the receding side of the rotating wheel). The effective wavelength is increased. Conversely, a person on the right-hand side would receive approaching waves of shorter wavelength.

Are there other physical meanings associated with these designs? Meditating on such relationships is a stimulating activity for both physics students and teachers. Are there relationships between physics and scanner art, technology, and beauty? The history of science records many examples of serendipitous insights linking phenomena from diverse areas.

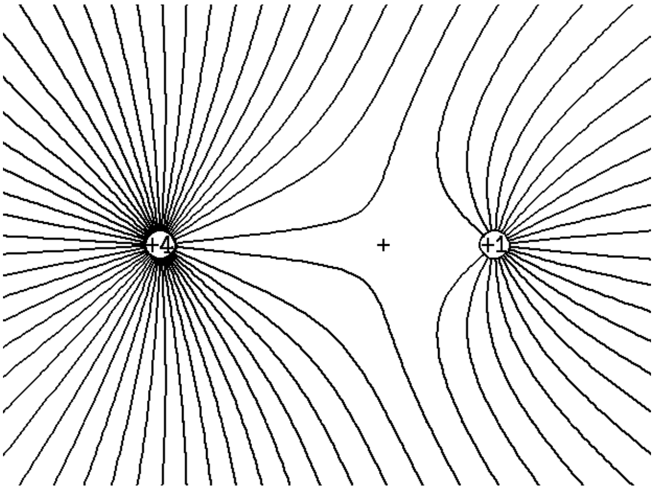


Figure 5. Two-dimensional electric field (without vector arrows) associated with two unequal electric charges. The neutral point in the field is marked with a cross.

Physics understanding is enhanced by predicting, observing, and explaining the outcomes of experiments. For example, what would happen to the pattern if the amplitude of oscillation was changed, but with the period kept constant? If the period was changed, with amplitude kept constant? If both were varied? These three questions alone generate a wealth of predictions that can be tested by the data collected. What would happen if the original pattern of Figure 2 was changed so that a wheel with 10 spokes, rather than 8, was used?

A Mathematical Analysis

Unfortunately, time limitations restrict the depth of physical and mathematical analysis students can handle in most secondary school courses. Nevertheless, in some curricula advanced students may well pursue a project based on a quantitative analysis of these, or similar, patterns. The following analysis is presented for those who have a special interest in this area, and concludes with some command lines that may be cut-and-pasted into *Graphmatica* (kSoft, 2005) software to create the shapes on the computer screen.

During scans, I was intent on turning the wheel at a constant rate, making exact timing of the period of rotation rather difficult. To quantify the rate, I used the diagrams of Figure 2 to calculate the ratio of the number of (360^0) rotations of the wheel to the period of the scan. The results, for scans 1 through 6, were 0, 0.13, 0.36, 1.2, 2.0, and 2.9 rotations per scan period, respectively.

My theoretical analysis yields the following parametric form of the curves:

$$x = 10 - t,\ y = (10 - t)\tan\left(\frac{\pi A t}{10} + \theta\right), \qquad (1)$$

where A is the turns of wheel per scan period (using values 0, 0.13, 0.36, 1.2, 2.0, and 2.9 to yield the scans in Figure 2). For each of these values of A, the eight spokes of the wheel are drawn one at a time, using for θ the values 0, π/8, 2π/8, 3π/8, 4π/8, 5π/8, 6π/8, and 7π/8). Incorporated in the equation are arbitrary values of 10 length units for the radius of the circle, and period of scan 20 time units.

Out of interest, I also changed the motion of the wheel from constant angular velocity to oscillation of the wheel with simple harmonic motion, yielding the results shown in Figure 6, scans 2 to 4.

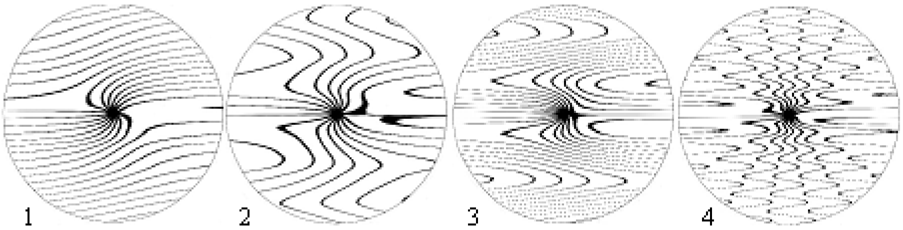


Figure 6. For scan 1, the direction of rotation was reversed half-way through the scan. For scans 2 through 4 the wheel was oscillated at varying rates through small amplitudes.

My analysis yields the following parametric form of the curves:

$$x = 10 - t,\ y = (10 - t)\tan\left(\Phi \sin\left(\frac{2\pi}{T} t\right) + \theta\right), \qquad (2)$$

where Φ is the angular amplitude, T the period of oscillation, and other variables the same as used in equation (1).

Computer plots of both equations using *Graphmatica* software agree very well with the scans in Figure 2, using, for example, command line

x=10-t; y=(10-t)tan(0.36*pi*t/10+a) {0,20} {a: 0, pi, pi/8}

for scan 3; and in Figure 6, for example, command line

x=10-t; y=(10-t)tan((0.5*sin(2*pi/7*t)+a)) {0,20} {a: 0,pi,pi/8}

for scan 2. Could scan 1 in Figure 6 perhaps represent some strange gravitational field in space, perhaps associated with a fast-spinning star dragging its gravitational field as it rotates?

Art and Technology

Lightly pasting different graphic designs to the underside of the disk in Figure 3 provides for endless possibilities for exploring scanner art. For example, the spoked wheel of Figure 2, scan 1 may be replaced with a square or a series of nested squares, a circle or series of nested circles, or a group of concentric circles. I have experimented with groups of grey-scale and coloured shapes, CD covers, and other artwork, rotating them at different rates and beginning the scan from different starting positions (Figure 7).

Consider scan 2 in Figure 2, in which the spoked-wheel pattern was rotated very slowly. The left side appears stretched, and the right side contracted. When the spoked wheel is replaced with the silhouette of a face looking to the left, rotation expands the face and contracts the back of the head, creatively distorting the original. I made an interesting caricature of a portrait of Albert Einstein showing a Pythonesque expanded brain and shock of hair, reducing to a narrowed chin (Figure 7).

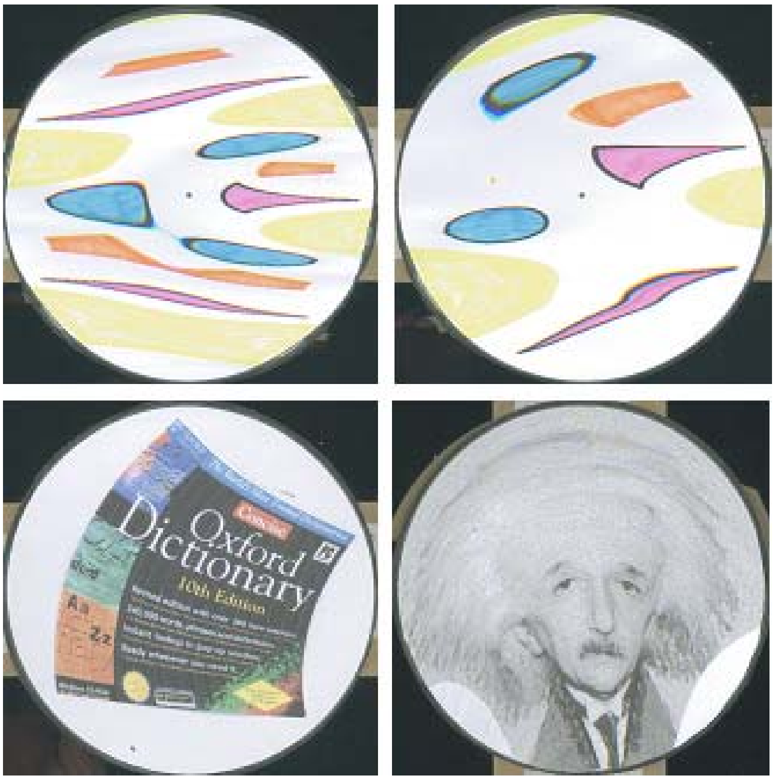


Figure 7. Scans of a few coloured squares and triangles, turned at different rates and starting at different orientations (*top*); of a CD cover (*bottom, left*); and of a photograph of Albert Einstein (*bottom, right*).

Conclusion

Two modes of scanning have been discussed; moving a shape at right angles to the scan, and rotating the shape about a central point. Many other forms of motion are possible, including free-form motion. It seems to me that younger children, less inhibited and often very confident with technology, could be very creative.

This article has presented scanner technology as a tool for generating designs that bridge physics, mathematics, and art. Its purpose is to stimulate teachers and students across all year levels to invent and explore their own applications, whether for fun or serious analysis.

Reference

kSoft. (2005). *Graphmatica*. Retrieved February 10, 2005, from http://www.graphmatica.com .

Ideas in Brief

Summaries of ideas from key articles in reviewed publications

Computer Projectors

Many, if not most, classrooms now have at least one computer. However, these computers are being underutilized for instructional purposes, mainly because it is difficult for 25 or so students to use a limited number of computers at the same time. A solution is to use a computer projector, a technology that has become increasingly affordable and which can be much more than just a glorified overhead projector (Bell & Garofalo, 2005).

A computer projector can:

1. bring technology access to all students in a room with only one or two computers.
2. increase student engagement, and improve conceptualization, by displaying still images (from the WWW, a CD-ROM, or a digital camera), multidimensional images (e.g., Chime molecule representations), animations, and video.
3. be used like a traditional demonstration, allowing a concept to be worked through without students needing to learn how to use a complex software application.
4. promote inquiry and analysis by projecting interactive simulations and spreadsheets. Have students suggest changes to the variables, predict the effects, and view the results immediately.
5. provide a focal point for a class, by bringing the whole class together to, for example, demonstrate how to use software or its features. This is beneficial in even a computer lab situation, or where all students have computer access in a classroom, and where different students will typically be focusing on something different at any instant.
6. be a money saver, by allowing a single copy software license to be purchased rather than a site license.

Reference

Bell, R. L., & Garofalo, J. (2005). Projecting science and mathematics. *School Science and Mathematics, 105*(1), 48-51.

Inquiry Classroom Management Checklist

Most of the techniques used to manage a direct-instruction classroom are inadequate for an inquiry setting, which is typically characterized by more movement, more noise, and more opportunities for students to misbehave. Indeed, concern over management issues, such as a fear of losing control of the classroom, is a major obstacle to the more widespread implementation of inquiry-based practices.

To help teachers address this issue, Sampson (2004) devised the Science Management Observation Protocol (SMOP). This 25-item assessment instrument, based on research about effective classroom management, allows a classroom observer to rate each item on a 0-4 scale. The following Inquiry Classroom Management Checklist is a modified version of the SMOP, written instead to facilitate teacher self-assessment.

Inquiry Classroom Management Checklist

Features of the Classroom

1. Do I have an effective way to get quiet in the classroom, within 10 seconds and without raising my voice or threatening punishment?
2. Do I consistently enforce a well-developed set of classroom rules, with interventions based on logical consequences?
3. Is there a set routine for students to get my attention?
4. Do students listen to me when I am talking, and do I avoid "talking over" them?
5. Is my lesson(s) student-centered and highly engaging, taking advantage of students' curiosity?

Student Collaboration

6. Do I use a variety of cooperative learning techniques to ensure that all students are engaged?
7. Are student groups small (3 students per group is generally ideal), with each student having a significant role in the group?
8. Are students' roles assigned effectively and fairly?
9. Do students respect the ideas and opinions of others?
10. Do I use structures to make each student personally accountable for content learned during a cooperative activity?

Time and Student Engagement

11. Do I inform my students of what they need to accomplish during a lesson, and give them a timeframe for doing so?
12. Are transitions between activities short (less than 60 seconds)?
13. Do I limit the number of instructions given before a transition or activity, and make them specific and clear?
14. Do I move continually around the room, listening to students, challenging them with questions, and keeping them focused?
15. Am I "with-it" (i.e., able to communicate an awareness of student behaviour), and able to do more than one thing at a time?
16. Is the majority of class time devoted to academic tasks?

Materials

17. Do I have an efficient method for stocktaking materials at the beginning, and end, of activities?
18. Is there a standard procedure for getting, and returning, materials?
19. Are my students accountable for keeping materials in good condition?
20. During lab work, do I move often between groups, but restrict student movement around the room?
21. Does inappropriate behaviour during lab work have a consequence, and is it documented?
22. Do I assign clean-up duties to specific students?

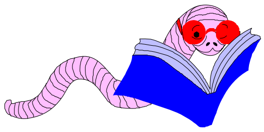
Safety

23. Have students been provided with a set of rules for laboratory work, and are they regularly reminded of them?
24. Do students know the location of safety equipment, and what to do in the event of an accident?
25. Do students wear safety glasses whenever heating, glassware, or chemicals are used?

While the above checklist identifies aspects that need to be addressed when planning to manage an inquiry classroom, it does not specify techniques for doing so. There may be multiple ways to effectively accomplish any particular checklist item, and such techniques could be gleaned by, for example, observing experienced teachers in action and by informal teacher-teacher collaboration. This journal will also make a contribution here. In the *Your Questions Answered* section of this issue, you will find a variety of suggestions for implementing the first item in the checklist (i.e., how to get all students in a class quiet and listening within 10 seconds). Other items in the checklist will be addressed progressively in subsequent issues.

Reference

Sampson, V. (2004). The science management observation protocol. *The Science Teacher*, *71*(10), 30-33.



Research in Brief

Summaries of research findings from key articles in reviewed publications

Use of Anthropomorphism and Animism in Science Instruction: What do Early Years Teachers Think About it?

By: Maria Kallery-Vlahos, Aristotle University of Thesaloniki, Greece
vlahos@helios.astro.auth.gr

Animism refers to the tendency one has to regard objects as living and conscious, while the tendency to ascribe to inanimate objects and nonhuman beings not only life, but also human characteristics such as feelings, desires, reasoning, and human capabilities, is called anthropomorphism. While controversial views have been expressed by several researchers and science educators as to whether animism and anthropomorphism should or should not be used in science instruction, teachers' opinions on this issue were never sought. Kallery and Psillos (2004) carried out a research project exploring Greek early years teachers' views on issues concerning the use of such formulations in science instruction, also investigating the reasons behind teachers' use of such constructs. Early years teachers were chosen because issues concerning the teaching of science become more complicated when it comes to children of very young age.

The early years teachers who participated in this study were implementing the national science curriculum for pre-primary education. This targets acquainting young children with science topics that concern properties of matter (e.g., floating and sinking, dissolving in water), atmospheric phenomena (water evaporation, rain, snowfall), concepts of light, sound, and motion, the Earth, Sun, Moon and the phenomenon of day and night, and plants and animals.

The results of the study showed that early years teachers do not share the view of some researchers that anthropomorphism and animism can aid young pupils' comprehension in science. They believe that use of these constructs can cause cognitive and--in special cases--emotional problems in children.

Cognitive problems. Teachers believe that the use of anthropomorphism and animism can confuse young children and cause them to form misconceptions and wrong impressions. They mentioned that, in their experience, very young children frequently find it difficult to make the transition from fiction to fact, and also to interpret metaphoric language.