

Your Stars - Revelation or Reassurance

Contents: A practical investigation of the validity of astrology.

Time: 2 periods.

Intended use: As part of any GCSE Science course which includes a consideration of the methods and processes of science.

Aims:

- To provide an opportunity to evaluate the reliability of predictions
- To show that it can be difficult to test predictions because of chance variation in the observations
- To develop awareness of the way in which statistical methods are used to evaluate the significance of experimental results
- To develop awareness of the difficulty of setting up an objective test in a context which involves beliefs and personal feelings
- To provide an opportunity to discuss the differences between science and pseudo-science.

Requirements: Students' worksheets No.907. Coins or computers for Part 2. An adapted horoscope from a recently published magazine for Part 3.

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Introduction

A lively account of the life and work of Johannes Kepler is given in *The Sleepwalkers* by Arthur Koestler (Penguin Books, 1986). Kepler began his career publishing astrological calendars and ended it as Court Astrologer to the Duke of Wallenstein. Koestler points out that Kepler rejected the then current practices of astrologers as quackery; but Kepler believed that there could be a new and true astrology.

Another source of information about Kepler is the chapter about him in the book *Cosmos* by Carl Sagan (Futura, 1983). While this does not explicitly discuss Kepler's astrological work, it does make the point that he badly wanted to believe in astrology (and other 'mystic' concepts), but that he ultimately put his scientific principles before his cherished beliefs. The chapter also highlights how the technique for predicting planetary positions, followed by an evaluation of the predictions, played a fundamental part in the formulation of Kepler's famous laws of planetary motion.

Popular astrology remains faithful to tradition and ignores the precession of the equinoxes. Astrologers use the vernal equinox as their reference point. The equinox moves eastward 1.4 degrees each century through the 'fixed' stars and a shift of 30 degrees has occurred in the past 2000 years. Zodiacal signs refer to 30-degree sectors of the ecliptic and not to constellations. Thus the traditional astrologers' sign of Aries coincides roughly with the real constellation of Pisces. However, there are sidereal astrologers who do take note of the movement of the Earth's axis relative to the stars and assign different dates to the birth signs.

Part 2 Testing predictions

The derivation of the 40 to 60 range quoted in the unit is given below. This information is included as background for teachers and it is not intended for the students.

Coin tossing is described by the binomial distribution. It is conventional to use the 5 per cent probability level when tests of significance are carried out. The 5 per cent level means that extreme results with only a 5 per cent chance of occurring are taken as evidence that the hypothesis under consideration is false.

In the example of tossing a coin 100 times, one can calculate the range within which 95 per cent of the results are expected to fall by the following (approximate) method:

Calculate the standard deviation, σ , of the binomial distribution. If p is the probability of success and q the probability of failure, then for n trials:

$$\sigma = \sqrt{npq}$$

For coin tossing $p = q = \frac{1}{2}$, so for one hundred tosses:

$$\sigma = \sqrt{100 \times \frac{1}{2} \times \frac{1}{2}} = 5$$

The mean = (number of trials) \times (probability of success) = $100 \times \frac{1}{2} = 50$

Now take $\pm 2\sigma$ from the mean as the 95 per cent range.

(The value 2 comes from the normal distribution and it is an approximation to apply it here.)

So for a hundred tosses there is a 95 per cent chance that the number of heads will lie between 40 and 60. (A more accurate calculation shows that the probability is 96 per cent.)

If a result is obtained which lies outside the 95 per cent range, it could have occurred by chance on only 5 per cent of the occasions on which the exercise is repeated. If this happens it is usual to conclude that the coin is biased or the method of tossing is biased. In drawing this conclusion one has a 5 per cent chance of being wrong.

A similar argument applies to the numbers of odds and evens in a list of randomly generated numbers. It is a more realistic exercise to check for bias in a calculator than in a coin. Some students might be interested to explore the effect of weighting a coin on one side — perhaps with Plasticine or Blu-tack.

Part 3 Your stars

Before starting Part 3 it might be a good idea to ask the students to suggest how they would plan to measure the reliability of horoscope predictions. Students may suggest keeping a note of the predictions over a week or so and then rating them for accuracy at the end of the period. This provides an opportunity to discuss the difficulty of deciding objectively whether or not a vaguely worded prediction has proved correct.

Requirements

For this part the teacher will need a horoscope from a recent newspaper or magazine — preferably a magazine published for younger readers. The horoscopes in weekly magazines are generally more detailed. Cut up the statements, re-order them and number them. Make copies for the students.

There is always a risk that one or two students may, by chance, have already seen the magazine chosen by the teacher and read their horoscope in it. They are unlikely to have read all the other eleven horoscopes, so the probability is high that they will remember which is 'theirs'. This could distort the results significantly with a small sample. The risk can be minimized: (a) by picking a magazine which has just been published and using it on the day of publication; and (b) by appealing to the students' honesty and asking them to withdraw from the exercise if they have seen the magazine in question.

The following examples show how to determine whether the results have any statistical significance for the size of sample involved. As in Part 2, it is not suggested that students should be shown the details of the statistics.

In this case there is a 1 in 12 chance of a student picking the correct statement.

$$p = \frac{1}{12} \text{ and } q = \frac{11}{12}.$$

For a class of 30 students

$$\sigma = \sqrt{30 \times \frac{1}{12} \times \frac{11}{12}} \approx 1.5$$

$$\text{The mean} = 30 \times \frac{1}{12} \approx 3$$

Rounded to whole numbers the 95 per cent range is about 3 ± 3

So the result will be significant at the 5 per cent level if more than 6 students pick the correct statement for their birth sign.

For one hundred students

$$\sigma = \sqrt{100 \times \frac{1}{12} \times \frac{11}{12}} \approx 3$$

$$\text{The mean} = 100 \times \frac{1}{12} \approx 8$$

Rounded to whole numbers the 95 per cent range is about 8 ± 6 . Any result in this range could happen purely by chance.

So the result will be significant at the 5 per cent level if more than 14 students pick the correct statement for their birth sign, in which case we might conclude that there is some validity in these predictions.

Part 4 You and your birth sign

The same statistics apply as in Part 3. The sample size could be increased if students take away a copy of the statements and ask other students in the school to take part in the exercise. The teacher will then have to help to collate and interpret the results as in Part 3.

The statements and signs are related as follows:

- A Virgo
- B Pisces
- C Libra
- D Capricorn
- E Scorpio
- F Gemini
- G Cancer
- H Aquarius
- I Leo
- J Aries
- K Taurus
- L Sagittarius

These statements are based on a set used in a study reported in the US in the 22 January, 1980 edition of the *National Enquirer*. That study claimed that an amazing 91 per cent of 240 randomly selected people picked the correct statement. A report in the *Skeptical Inquirer* (Winter 1980-81), describes a study which attempted to replicate the earlier work. The second investigation found that only 26 out of 262 students chose the correct statement. This is in the range expected by chance.

Further resources

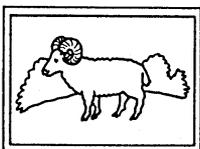
Another way of testing astrological predictions is given on pages 164-5 of Nuffield Science 11-13, *Pupils' Book I, How Scientists Work* (Longman, Harlow, 1986). The approach is discussed on pages 165-6 of the corresponding *Teachers Guide I*.

YOUR STARS — REVELATION OR REASSURANCE?

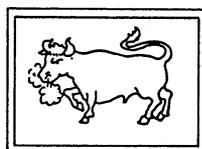
Astrologers believe that a person's character is determined by the position of the sun, the moon, the planets and the stars at the moment of birth.

Astrologers also try to predict what is going to happen. Have you ever studied 'Your Stars' in a newspaper? If so you have been trying to find out about your future. You have been looking for help with *predicting* what will happen to you in the days or weeks ahead.

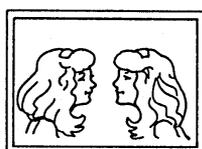
The predictions of astrologers are linked to the signs of the zodiac. The zodiac is the part of the sky where we see the sun, the moon and the planets against the background of the stars. The groups of stars in the zodiac have names and symbols, as shown in Figure 1. Everyone is born under a particular sign of the zodiac. This is the group of stars in which the sun appeared when you were born.



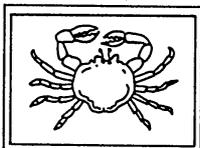
Aries the ram
March 21 — April 19



Taurus the bull
April 20 — May 20



Gemini the twins
May 21 — June 21



Cancer the crab
June 22 — July 22



Leo the lion
July 23 — August 23



Virgo the virgin
Aug. 24 — Sept. 23



Libra the scales
Sept. 24 — Oct. 23



Scorpio the scorpion
Oct. 24 — Nov. 21



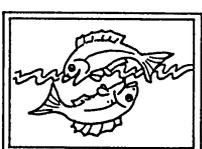
Sagittarius the archer
Nov. 22 — Dec. 21



Capricorn the goat
Dec. 22 — Jan. 19



Aquarius the water carrier
Jan. 20 — Feb. 18



Pisces the fish
Feb. 19 — March 20

Figure 1 The signs of the zodiac

Now answer questions 1 and 2.

This unit is in four parts:

Part 1 is about the way scientists make predictions

Part 2 shows that it can be difficult to test predictions

Part 3 asks you to investigate whether there is any value in the predictions made by astrologers

Part 4 asks you to test whether there is any connection between someone's birth sign and their character.

Johannes Kepler

We now remember Johannes Kepler as a famous astronomer. His first job was at Gratz in Austria where he was a teacher of astronomy and mathematics. Part of his job was to publish an annual calendar of astrological forecasts.

Kepler cast his own horoscope and wrote:

'Johannes Kepler, Kepler, Khepler, Khepler, Keplerus was conceived on 16 May A.D. 1571, at 4.37 a.m., and was born on 27 December at 2.30 p.m., after a pregnancy lasting 224 days, 9 hours and 53 minutes.'

Kepler was vague about the spelling of his name but very precise about the moment of his birth.

Questions

- 1 What is the difference between astrology and astronomy?
- 2 Do you think that there are now official mathematicians and astronomers who earn money by casting horoscopes?

Part 1 Making predictions

Scientists are in the business of trying to work out what will happen in the future. They use their observations and theories to make predictions. For example, the weather forecasts on TV are made by scientists called meteorologists.

Scientists make predictions to test their theories. If you have studied chemistry you may know that in 1869 a Russian chemist called Dmitri Mendeleév suggested that there were still some elements to be discovered. He predicted their properties. He based his predictions on his new Periodic Table. In a few years the missing elements were discovered. Mendeleév's predictions were found to be correct.

Some theories are more definite than others. They can be used to make more accurate predictions. Here is a list of ten more examples of predictions.

- A** Meteorologists predict what the weather will be tomorrow.
- B** Astronomers predict where to look for planets in the night sky for years ahead.
- C** Risk analysts predict the number of cancer deaths caused by cigarette smoking.
- D** Gamblers predict the scoring draws for the football matches on a Saturday afternoon.
- E** Physicists predict the size of the electric current which will flow in a circuit when the switch is closed.
- F** Environmental scientists predict how burning fossil fuels will affect the climate.
- G** Doctors predict how long it will take for a broken bone to heal.
- H** Forensic scientists predict the age, sex and size of a criminal from observations made at the scene of the crime.
- I** Chemists predict the amount of metal which can be extracted from an ore.
- J** British Rail timetables predict when InterCity trains will arrive.

Now answer questions 3 and 4.

Questions

- 3 *Look at the ten examples of scientific predictions A to J listed on this page. List the predictions in order of the accuracy you expect them to have. Put the letter of the most accurate prediction first, and the least accurate prediction last. Compare your order with the order of other people in your group and discuss the differences.*
- 4 *Now see if you can think of some more examples of predictions. Add your examples to your list from question 3.*

Part 2 Testing predictions

Testing predictions is not as easy as you might expect. Think about spinning a coin. You expect that there is a 50-50 chance that it will come down 'heads'. Suppose you spin a coin ten times and you get 'heads' six times and 'tails' four times. Does that make you change your mind about the chances? What if you spin the coin a hundred times and get 'heads' 47 times? What will happen if you toss it a thousand times?

- When you toss a coin you expect some variation from the 50-50 rules just by chance.
- The more times you toss a coin the closer you are likely to get to 50 per cent 'heads' and 50 per cent 'tails'.

The methods of statistics are used to decide whether something is likely to happen just by chance. Statistics suggest that there is a 96 per cent chance that if you spin a coin a hundred times you will find that the number of 'heads' is between 40 and 60. There is only a 4 per cent chance that you will get less than 40, or more than 60 heads. This is so unlikely that if the number of heads is outside this range you may conclude that you have a biased coin. In making this conclusion you have a 4 per cent chance of being wrong.

Now try activity A or B.

Activity A

Spin a coin ten times. Record the number of times it comes down 'heads'. Now spin it another ten times and record the number of heads. Keep doing this until you have spun the coin a total of one hundred times. How many 'heads' do you get in each lot of ten spins? How many heads do you get for all one hundred spins? What do you find if you add all the results from the whole class?

Activity B

Use a computer to generate a series of random numbers. Produce a list of one hundred numbers. Count the number of even numbers. How many even numbers would you expect? What is the chance variation likely to be? Is your computer biased or not?

Part 3 Your stars

The predictions made by astrologers are called **horoscopes**. You and your class are going to test the predictions made in a magazine or newspaper horoscope. If possible you will use a horoscope aimed at people of your age.

Most horoscopes in the papers make predictions about just a few types of daily or weekly events. They are about such things as friends, family life, work, money and travel.

Your teacher will have chosen a horoscope for a recent day or week. You will be shown twelve predictions — one for each sign of the zodiac. The predictions are numbered but you do not know which goes with which sign. Read them carefully and pick the one which best describes what happened to you during the chosen day or week.

Write down your birth sign and the number of the prediction which you have chosen.

Your teacher will collect the results from the whole class and together you will check the accuracy of the horoscope.

A sample of 20 to 30 from a class is rather small. If each member of the class asks other students to make the same choice you may be able to get a sample of 100 to 200 choices. This will be a better test.

Now answer questions 5 to 8.

Questions

- 5 *Why choose to test a horoscope designed for people of your age? Do you think that newspaper horoscopes are prepared for young people?*
- 6 *How easy is it to pick the horoscope which describes what has happened to you? Do you think that astrologers choose their words carefully?*
- 7 *Do you agree with this statement:
'The astrological predictions in newspapers are worded so generally and vaguely that they could apply to anyone. This is why people think they work.'*
- 8 *Do you think that this has been a fair test of horoscopes? How might you improve the testing?*

More questions for discussion

- 9 *Do you think that horoscopes work better for people who believe in them?*
- 10 *Some people think that newspapers should print a warning above their horoscopes. The warning might say: 'The following astrological forecasts should be read for entertainment value only. Such predictions have no reliable basis in scientific fact.' Do you agree with this idea?*
- 11 *Can you think of scientific reasons why your character might be affected by your birth sign?*
- 12 *Apart from your birth sign, what other factors might affect your character? Suggest five or more factors and put them in order. Put the most important one first.*

Part 4 You and your birth sign

Does your birth sign really affect your personality? Look at the list of statements below and pick the one which best describes you. There is one statement for each birth sign — twelve statements altogether.

- A** I am a perfectionist. I pay attention to small, important details that others often forget. I hate to let a job go until it is finished properly. Others may find me critical but I am more critical of myself than of them.
- B** I am an 'easy touch'. I would rather help people than make a lot of money. I enjoy day dreaming. I usually get good results by trusting my feelings and following my hunches.
- C** I am very interested in all of the creative arts, such as writing, art and music. I like to settle arguments between my friends. I'm good at this because I can see both sides of an issue.
- D** I am very good at making money. I like taking charge and being a leader. I have my sensitive, emotional side, but I show this only to those closest to me. In public, I prefer to remain cool and collected at all times.
- E** I like to finish whatever I start. My strong determined personality makes me succeed. I can be jealous. I am very passionate.
- F** I like to create with words either in writing or in speech. I may sometimes dominate conversations. My friends find me witty and interesting, though not always loyal. I am usually logical and cool but change moods quickly and often.
- G** Family is important to me and I will want to have children. I feel happiest when at home with my family, and pets. I like to spend time helping about the home and cooking.
- H** My mind is filled with new ideas and I like to invent things. I like to feel that I am in control of my life. I like to be organized and efficient. I like to learn and I have a good memory for facts.
- I** I am very happy and cheerful. I like making others happy. I am openly emotional and usually optimistic. I like to be looked after and cared for; but I am generous in return.
- J** I am so enthusiastic about life that I am active at something all the time. I usually have five things going at once. I will work long hours on a project if it interests me. I love to talk and talk quickly. I sometimes exaggerate.
- K** Once I make up my mind, I don't like to change it. I can be stubborn, especially when I know I'm right. I am too easy going and quiet to get into arguments over anything.
- L** My love of the outdoors and sports shows me to be a person who hates being tied down in any way. Freedom is what I need. I love animals, travel and humour.

Write down your birth sign and the letter of the statement which you have chosen.

Now answer question 13.

Question

13 Suppose that a hundred students pick a statement. How many would you expect to choose correctly the statement for their sign just by chance?