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RETROSPECTIVE VS. PROSPECTIVE ANALYSES OF SCHOOL INPUTS: THE CASE OF FLIP CHARTS IN KENYA

Paul Glewwe
Michael Kremer
Sylvie Moulin
Eric Zitzewitz

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ABSTRACT

This paper compares retrospective and prospective analyses of the effect of flip charts on test scores in rural Kenyan schools. Retrospective estimates that focus on subjects for which flip charts are used suggest that flip charts raise test scores by up to 20 percent of a standard deviation. Controlling for other educational inputs does not reduce this estimate. In contrast, prospective estimators based on a study of 178 schools, half of which were randomly selected to receive charts, provide no evidence that flip charts increase test scores. One interpretation is that the retrospective results were subject to omitted variable bias despite the inclusion of control variables. If the direction of omitted variable bias were similar in other retrospective analyses of educational inputs in developing countries, the effects of inputs may be even more modest than retrospective studies suggest. Bias appears to be reduced by a differences-in-differences estimator that examines the impact of flip charts on the relative performance of students in flip chart and other subjects across schools with and without flip charts, but it is not clear that this approach is applicable more generally.

Paul Glewwe
Department of Economics
University of Minnesota
1035 Mgmt. & Econ. Bldg.
271 19th Avenue South
Minneapolis, MN 55455
and The World Bank

Michael Kremer
Department of Economics
Harvard University
Littauer Center 207
Cambridge, MA 02138
and NBER
mkremer@fas.harvard.edu

Sylvie Moulin
The World Bank

Eric Zitzewitz
Department of Economics
MIT
50 Memorial Drive
Cambridge, MA 02139

Introduction

Most analyses of the effect of educational inputs are based on retrospective studies, which compare schools with different levels of inputs (Hanushek, 1995). One potential weakness of this approach is that observed inputs may be correlated with omitted variables that affect educational outcomes. This could potentially bias outcomes in either direction. For example, if parents who provide better home environments for children tend to organize politically to obtain more school inputs for their children, estimates of the effect of these school inputs on test scores may be biased upwards. On the other hand, if compensatory programs provide schools in disadvantaged areas with additional inputs, then retrospective studies may underestimate the effect of these inputs. The direction and severity of these biases is ultimately an empirical question. This paper compares retrospective and prospective estimates of the effects of flip charts in Kenyan primary schools.[3] We find that prospective estimates are much smaller than retrospective estimates, suggesting that retrospective estimates are subject to serious upward omitted variable bias, even when controlling for observable inputs.

Straightforward OLS regressions using retrospective data on test scores in subjects in which flip charts are used suggest that flip charts raise student test scores by 21 percent of a standard deviation. Controlling for other observed school inputs affects these estimates only slightly. Difference in difference estimates that compare the impact of flip charts on the relative performance of students in flip chart and non-flip chart

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[2] Glewwe, University of Minnesota and World Bank; Kremer, Harvard and NBER; Moulin, The World Bank; Zitzewitz, MIT.

[3] We thus follow the approach LaLonde [1986] used in the context of U.S. job training programs.

subjects suggest a smaller effect of about 5 percent of a standard deviation, but this effect is still significant in some specifications.

These retrospective results contrast with those from a prospective, randomized evaluation comparing 89 schools that were randomly chosen to receive flip charts with 89 schools that did not receive flip charts. After two years, test scores in subjects where flip charts can be used are virtually identical in the two types of schools (0.6 percent of a standard deviation lower in the schools that received flip charts, with a standard error of 4.8 percent). The analogous retrospective estimate of an increase of 20 percent of a standard deviation is decisively rejected. A differences-in-differences estimator that compares the impact of flip charts in the relative performance of students across flip chart and other subjects also yields an estimate that is effectively zero (0.8 percent of a standard deviation, with a standard error of 3.1 percent).

These results suggest that using retrospective data comparing test scores in subjects covered by flip charts between schools with and without charts to determine the effect of purchasing charts for all schools would have seriously overestimated the charts' effectiveness. A differences-in-differences approach that compares relative performance across subjects reduces but does not eliminate this problem. It is not clear that such a differences-in-differences approach has general applicability, however.

Given the scarcity of compensatory programs in developing countries, it seems reasonable to hypothesize that omitted variable bias will typically be positive in retrospective estimates of school inputs in developing countries. This suggests that the effect of large-scale programs to provide inputs may be even smaller than suggested by retrospective studies. As discussed by Hanushek (1995), these studies often find little or no effect of inputs.

The remainder of this paper is divided into four sections. The first describes the primary education system in Kenya, the flip charts, and the data collected. The second section presents retrospective estimates of the flip charts' effect on test scores. The third section presents prospective estimates. A fourth section discusses potential biases from missing data, and a final section concludes the paper.

I. Background

The vast majority of Kenyan children attend primary school, although less than half reach grade 8. Entrance into secondary school is highly competitive, based on students' performance on the Kenya Certificate of Primary Education (KCPE) exam, which is taken at the end of grade 8.

The schools in the study are located in Busia and Teso, two neighboring agricultural districts on the border with Uganda, both of which have below-average income for Kenya. Flip charts and other visual aids are rare in schools in these areas, and less than one-third of the schools had any flip charts before the study. Even textbooks are rare in these schools. In grade 8, which is selective, about 40 percent of students had textbooks in math and English, but 15 percent or less had textbooks in science and other subjects. In lower grades, textbooks are much rarer.

A Dutch NGO, International Christilijke Steunfond, provided the flip charts distributed in the prospective study: two sets of science charts (one covering agriculture and the other covering general science), as well as a teacher's guide for science, one set of charts for health, one set of charts for mathematics, and a wall map of East Africa for geography. Each set of charts contains about twelve individual charts spiral bound together. Each individual chart covers different aspects of the topic (a copy of the math chart is attached at the back of this paper). The charts are not kept in the classroom, but rather are brought in when they are relevant to the day's lesson, and can therefore be used in more than one grade. The science charts are appropriate for grades 5-8, while the simplest math charts could, in principle, be used in grade 3. In practice, the grade 7 and 8 teachers have priority over the usage of the charts, and account for roughly 60-75 percent of total use, based on a survey in which teachers reported the number of times they had used the charts.

There are several reasons why visual aids such as flip charts might promote learning. Almost all students recall having seen pictures more often than having read words or sentences (Shepard, 1967). In addition, learning styles vary across students, so adding visual aids to traditional auditory presentations of material may reach a broader range of students.[4] Studies have found that supplementing textbooks with visual aids promotes learning in many different subjects, such as social studies (Davis, 1968), anatomy (Dwyer, 1970), ecology (Holliday, 1973), and reading (Samuels, 1970). Live presentations also benefit from supplementation with visual aids (see Dwyer, 1970, and Holliday and Benson, 1991). For caveats and alternative views, however, see Dwyer (1970), Holliday and Benson (1991), Levin (1976), and Lookatch (1995).

[4] For example Dunn et al. (1989) find that over 40 percent of students in the United States are visual learners, compared with under 10 percent auditory and about 20 percent tactual (touch) and 30 percent kinesthetic (activities). Wallace (1995) finds similar results for the Philippines.

Flip charts may be particularly attractive in the rural Kenyan setting, where textbooks are too expensive for most students and many students have limited proficiency in English, the medium of instruction in Kenya and the language in which all Kenyan textbooks are written. Glewwe, Kremer, and Moulin (2000) find that textbooks improve scores only for students in the top two quintiles of the distribution of pre-test scores.

Test score data

The data we have available are the test scores of grade 8 students on the KCPE in November 1997 and October 1998, the scores of grade 8 students on practice exams given in July 1997 and 1998, and the scores of grade 6 and 7 students on practice exams given in July 1998.[5] Practice exams closely follow the format of the KCPE and are set at the district level by the Ministry of Education. Each exam covers 7 subjects: English, Swahili, Math, Science/Agriculture, Geography/History/Civics/Religion (GHC-RE), Arts/Crafts/Music (ACM), and Home Science/Business Education (HS-BE). Of these seven subjects, the flip charts received were relevant to four: Math, Science/Agriculture, Home Science/Business Education (which includes health), and Geography/History/Civics/Religion (the wall map). Each subject exam consists mainly of four-answer multiple-choice questions, although the English and Swahili exams also require students to write a composition. The 1998 practice exams were administered only in Busia district (they are missing for the two divisions that split off during 1997 to form the new Teso district), but both 1997 exams and the 1998 KCPE exam are available for both districts. In addition to these data on (post-intervention) performance in 1997 and

1998, there are also (pre-intervention) data on average school-level performance across all subjects from practice exams in 1996. There are no data for individual subjects or students in 1996.

All test scores are standardized using the individual-student mean and standard deviation for each grade-test-subject combination in the comparison schools. A score of 0.2, for example, represents someone who scored 0.2 standard deviations above the average in the 89 comparison schools. For reference, it may be useful to note that a movement from the 50th to the 54th percentile of the distribution corresponds to an improvement in test scores of 0.1 standard deviations (10 percent of a standard deviation).

II. Retrospective Analysis

For the retrospective analysis, we used data for 100 schools involved in a separate study that provided textbooks and grants to randomly selected schools (described in Glewwe, Kremer, and Moulin (2000)). Data for these schools on flip charts and other school inputs were collected in early 1998 and the effect of the inputs was estimated using the 1998 practice and KCPE exam data for grades 6-8. Data were only available on the total number of flip charts, not their subject, and wall maps were not included. Since wall maps were not included for the purposes of the retrospective analysis, the flip charts could potentially be relevant to three subjects: Math, Science/Agriculture, and Home

[5] Unlike 1996 and 1998, in 1997 this practice exam was given only to grade 8 students.

Science/Business Education. Data on the availability of flip charts were available for 83 schools; when controlling for other inputs, the sample drops to 79 schools.

Since the data for these schools provide information only on the total number of science, math, and health science-business education (HS-BE) charts in the school, not the number in each subject, we estimate the average effect charts across all three subjects. Since the program evaluated in the prospective study distributed four flip charts (2 Science, 1 Math, 1 HS-BE), we divide the number of charts variable by four to generate coefficients that are comparable with the retrospective analysis.

Table 1 presents results from regressions of test scores on flip charts and other school inputs. In all regressions, data from multiple subjects and four grade-test combinations (practice exam for grades 6-8 and KCPE for grade 8) are combined into a single regression. Columns 1-4 estimate the effect of flip charts in the three flip chart subjects. Columns 5 and 6 present results from a difference-in-differences specification that compares the impact of flip charts on the relative performance of students in the three flip chart and the four non-flip chart subjects. All regressions include subject and grade-test fixed effects, and controls for whether the school was in a group that received textbooks or grants through another program, (the omitted category is the comparison group for that program). Thus, the coefficient on books per pupil reflects only variation in textbooks due to other factors, primarily the number of books prior to the program. Regressions also include school random effects to allow for within school correlation in test scores for example, due to differences in headmaster quality.

The results in columns 1-3 suggest that adding flip charts raises test scores by about 20 percent of a standard deviation in flip-chart subjects, an estimate which is significant at the 5 percent level. Controlling for other school inputs makes little difference to the estimates.

The estimators in columns 4-6 implicitly compare the relative performance of flip charts in flip chart and non-flip chart subjects. The effect of flip charts is estimated by comparing, across schools with and without flip charts, the difference between scores in subjects where flip charts are used and scores in other subjects. The validity of this approach is open to question. Some question whether it is possible to add and subtract test scores in different subjects, given their ordinal, rather than cardinal nature (Krueger and Whitmore, 2000). Aside from this issue, these estimators will only be valid if flip charts have no effect on test scores in non-flip chart subjects, and if other factors correlated with flip charts that could influence scores do so equally across all subjects. Each of these assumptions is open to question. Flip charts could potentially either raise or lower test scores in other subjects. They could raise test scores by improving pupils' general interest in school, and thus attendance, or they could lower scores by diverting pupils' or teachers' attention from non-flip chart subjects.[6] Moreover, since different tests were given in different subjects, an omitted variable correlated with flip charts, such as headmaster characteristics, could potentially differentially affect test scores in different subjects.

Column 4 controls for the performance of students in non-flip charts subjects; this reduces the estimate to 7.6 percent, but this estimate remains significant. The differences-in-differences estimates in columns 5 suggest that providing four flip charts would raise test scores by 4.9 percent of a standard deviation in the three flip chart subjects. Given that these regressions compare results across subjects, and that the performance of students in a particular school in a particular subject may be correlated due to teacher ability, column 6 allows for random effects at the level of interaction between schools and subjects. This reduces the point estimate to 4 percent, and considerably reduces the significance level given the small sample size. The differences-in-differences regressions also suggest that flip charts raise test scores by 15-16 percent in non-flip chart subjects, suggesting either that flip charts have a positive effect in non-flip chart subjects or that the direct estimators are inflated by an omitted variable bias problem that controlling for other school inputs does not alleviate.[7]

The retrospective analysis makes flip charts look cost effective compared to textbooks. The per-pupil cost of providing four charts is only 10 percent of the cost of providing a textbook for every pupil in each of the three subjects,[8] but the retrospective estimates suggest that the flip chart effect is about 50 percent larger than the effect of providing textbooks for each pupil in three subjects (from column 2, comparing 0.194 -- the effect of four charts -- with 0.125). Since flip charts are much less expensive, the relative cost-effectiveness of these two interventions is much higher, with flip charts being about 15 times more cost-effective than textbooks, in terms of dollars per average

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[6] Note, however, that in the upper grades, the school day is divided into separate periods with different teachers for different subjects.

[7] A caveat to the retrospective analysis is that the significance of some of the results is caused by the inclusion of one school with well above average test scores and 15 charts (compared with an average of 1.1 per school). Although we have no reason to doubt this data, treating the school has having only 5 charts reduces the estimates in column 2 to 18 percent with a standard error of 16 percent. The differences-in-differences estimate in column 4 remains significant and increases slightly in magnitude, however.

[8] Wall charts cost about US$20 each, so four would cost $80. Textbooks in Kenya cost approximately $3.33; it would therefore cost about $800 to provide one textbook per pupil in each of three subjects to the 80 students in grades 6-8 at the average-sized school in the sample. These cost figures are from 1997 and are converted to US$ at the then current exchange rate of 60Ksh/$.

test score gain. Even though the differences-in-differences estimate is much smaller than the direct estimate, it still suggests that flip charts are 3-4 times as cost-effective in raising average test scores as textbooks. As discussed below, a prospective analysis does not support this conclusion.

III. Prospective Analysis

International Christelijk Steunfonds (ICS), a Dutch non-governmental organization, distributed flip charts to selected schools in Busia and Teso in 1997. One hundred and seventy-eight schools were potentially eligible. Schools that ICS had previously assisted through the textbook and grant program or through other programs were ineligible, as were a smaller number of relatively well-off schools. Since ICS began assisting schools that were relatively poor, those participating in the textbook/grant study tended to be slightly worse performers than those in the flip chart study, and since the best off schools were excluded, those in the flip chart study had roughly similar mean scores as the district as a whole.[9] Table 2 shows that the average pre-intervention characteristics of these 178 schools were nonetheless fairly close to those of the district as a whole. The assignment of the 178 schools into flip chart and comparison groups was done as follows; the schools were sorted alphabetically, first by geographic district, then by geographic division, and then by school name. Then every other school on that list

[9] If flip charts were more helpful for weaker students, part of the difference explanation for larger estimated effect for the retrospective could be that these schools had lower average 1996 test scores. Interaction regressions in both the retrospective and the prospective sample found no evidence that the effect of flip-charts was greater for schools with low initial test scores. The point estimates for the interaction coefficients suggested that the effect of flip charts would be between –0.4 and 0.2 percent higher in the retrospective sample; these point estimates were statistically insignificant.

was placed in the flip chart group. The two types of schools will henceforth be referred to as flip-chart schools and comparison schools, respectively. The flip chart program was announced in January 1997, after the start of the 1997 school year (in Kenya the school year runs from January to November), and the charts were distributed in early February 1997. Each school received two sets of science charts (including a teacher's guide), one set of charts in math, one set in health, and a wall map.

Table 3 contains the average raw scores out of 100 for each test and grade for the flip chart and comparison schools in the prospective study. The most straightforward method of evaluating the effect of the randomized distribution of flip charts is to compare the post-intervention (1997 and 1998) scores in the 89 flip chart schools with the scores in the 89 comparison schools. The last four columns of Table 3 provide average test scores across all seven subjects for the flip chart and comparison schools for each test and grade combination. The flip chart schools scored equal to or slightly below the comparison schools on the grade 8 exams and slightly above the comparison schools in grades 6 and 7 on the July 1998 exam. In all cases, the differences are much less than 10 percent of a standard deviation of the distribution for the comparison group.

Table 4 presents random effects regression estimates of the difference in test scores between flip chart and comparison schools for each subject. Data from all tests are pooled to construct these estimators. School random effects are included to allow for correlation in the error term among students within a school, and these school random effects are allowed to vary by year. Results are presented with and without controls for pre-intervention (1996) school-average test scores. Controlling for pre-intervention test scores reduces the size of the school random effect, improving the efficiency of estimation. For science-agriculture, the subject for which two sets of flip charts and a teacher guide were given, test scores for the flip chart and comparison schools were almost identical; the same is true for Geography/History/Civics/Religion. For math and Home Science/Business Education, scores in flip chart schools were 2-3 percent of a standard deviation below those of comparison schools. None of these differences is statistically significant. Even if we limit the analysis to the subject-grade combinations in which charts appear most promising, namely Math and Science in grades 6 and 7, a procedure that is obviously open to criticisms of data mining, we still do not obtain a t-statistic greater than one. In summary, there is little evidence in Table 4 that suggests flip charts had a positive impact on test scores.

Tables 5 and 6 present estimates that pool across subjects. In Table 5, the estimate of the difference between flip chart and comparison schools is allowed to vary for the four flip-chart subjects and the three non-flip chart subjects. This estimation includes random effects for school, school-subject combinations, and pupils.[10] Controlling for pre-intervention school-average scores and combining all tests, test scores in schools that received flip charts are estimated to be 0.6 and 1.4 percent of a standard deviation lower in flip chart and non flip-chart subjects, respectively, with standard errors of roughly 5 percent of a standard deviation. Again controlling for pre-intervention school-average scores, scores are 3-7 percent of a standard deviation lower in flip-chart schools in both groups of subjects in 1997, while they are 2-6 percent of a standard

[10] Due to computational constraints, pupil random effects could not be included in the regressions which include all subject-grade-test combinations. Despite the large size of the pupil random effects, the results for the single-test, multi-subject regressions change very little when pupil random effects are omitted. Flip chart effects change by no more than 0.45 percent of a standard deviation, and standard errors increase by

deviation higher on the 1998 practice exam. None of these differences are close to being statistically significant (none has a t-statistic over 0.75), nor is the slight improvement from 1997 to 1998 statistically significant in regressions that estimate separate flip-chart effects for each year for 8th graders (not shown).

The results in Table 5 suggest that the overall performance of a school can vary from year to year across subjects. This variation in the cross-subject school effect adds noise to the estimated difference between test scores in flip chart and non flip chart schools. An alternative approach is to assume that flip charts do not affect performance in non flip-chart subjects and estimate the effect of flip charts by comparing the relative performance of flip-chart schools in flip chart and non flip chart subjects with the analogous relative performance in the comparison schools. Under the assumption that flip charts do not affect non-flip chart subjects, we can improve the efficiency of estimation by using the non-flip chart subjects to better control for school effects. Table 6 presents estimates of the difference in the flip chart-comparison school performance differential between flip chart and non flip-chart subjects. Across all subjects and test-grade combinations and controlling for past performance, the effect of flip charts is estimated to be 0.8 percent of a standard deviation. The standard error of the differences-in-differences estimator is lower (3.1 percent of a standard deviation), but the estimated effect of flip charts is still far from significant.

Across all the different estimators in the prospective study, the effect of flip charts appears to be essentially zero. There is no evidence that this is because flip charts were

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0.1 percent of a standard deviation for 8th grade and decrease by 0.04 percent for 6th and 7th grade, when pupil random effects are omitted.

not used. We interviewed 82 grade 7 and 8 teachers in flip-chart subjects at 21 of the schools that received flip charts. Ninety-eight percent of the teachers were aware that their school had been given flip charts, and 91 percent claimed to have used the flip charts. In no cases had the flip charts been lost or stolen. Ninety-two percent of teachers claimed they found the charts helpful, and they reported that the average chart had been used in each class on 10-20 percent of school days in the current year (1998). Given that the charts were shared between grades 6-8 at least, this represents reasonably high utilization of the charts. One caveat is that although teachers were surveyed in private and told that their answers would be kept confidential and would not affect future aid to their school, the teachers may have nonetheless felt an incentive to bias their usage estimates upward. Yet over ninety percent of the teachers gave specific answers to questions that required some experience using the charts (e.g., which charts did they find most and least helpful, and why), which suggests that the charts had at least been used.

The incentives faced by schools in Busia may have led them to use the charts for students in upper grades, who would soon take the KCPE exam on which schools are judged. The flip chart use survey revealed that charts were used an average of 13 days per 75-day term in grade 8 compared to 7 days each in grades 6 and 7. One potential hypothesis for the low estimated effect of flip charts is that the charts would have been more useful in lower grades. Thirty percent of grade 7 and 8 teachers reported that the charts helped the worst students the most, while only three percent reported that they helped the best students most. The fact that the estimated effect of the flip charts was highest for grade 6 students is at least consistent with the charts being more appropriate for those students. However, neither the estimated effect for grade 6 nor the difference in estimated effect between grade 6 and the higher grades is statistically significant. We also used quantile regressions to test whether flip charts had a greater impact for lower-ability students and found that the coefficients from the quantile regressions did not differ with those from mean regressions by more than one percent of a standard deviation and remained insignificant.

Note that even the lowest retrospective estimate implies that the program should have raised scores by four percent of a standard deviation, while the levels retrospective estimator suggests that it should have raised scores by 20 percent of a standard deviation. The latter possibility is rejected by the prospective study, although the former is within a 95-percent confidence interval.

IV. Missing data and potential biases

The results of both the prospective and retrospective evaluations could be biased if the probability of our observing the test score of pupils of different ability were affected differentially by the flip charts. In particular, both estimates could be biased downward if flip charts induced more low-ability students to take the exams. We do not have data to check this for our retrospective estimates, but in the prospective study, absenteeism rates for each exam were very similar in the treatment and control schools. Probit regressions (not shown here) reveal that the differences in absenteeism are not significant, and the magnitude of the differences is small enough that even if it were the worst students that missed the tests, the effect on the average result would be small.

More specifically, absenteeism rates for flip chart and comparison schools in 1997 were 2.2 and 2.4 percent for the practice and 1.0 and 1.2 percent for the KCPE exam. Absenteeism rates for flip-chart and comparison schools for grade 8 in 1998 were 6.3 and 3.8 percent for the practice exam and 3.5 and 3.1 percent for the KCPE exam; absenteeism for the practice exam was 10.8 and 10.8 for grade 6 and 9.4 and 6.9 for grade 7. The largest differences were for the 1998 grade 7 and 8 practice exams, where absenteeism for flip-chart schools was 2.5 percentage points higher. If the marginal student was one standard deviation below the mean on each individual test, this difference in absenteeism would lead to an *overestimate* of the relative performance of the treatment schools by 2.5 percent of a standard deviation on these two tests; the differences for the other exams would be trivial. The assumption that non-takers would score one standard deviation below the mean is probably extreme given that in 1998, 8th graders who did not take the KCPE scored only 0.1 standard deviations on the practice exam below those who did. It is therefore unlikely that absenteeism is responsible for the results.

In addition, due to illegible or lost score recording sheets or non-administration of the exam, 6, 14, 15, 14, 1, and 2 schools were missing scores for the 1997 grade 8 practice and KCPE, 1998 grades 6-8 practice, and 1998 grade 8 KCPE, respectively. Roughly half of the school missing data were comparison schools (4, 8, 6, 8, 1, and 2, respectively). The missing schools were roughly average performers on the 1996 tests, so their omission should not systematically affect the results, and any effect should be mitigated by controlling for 1996 test performance. For example, the difference between the average raw 1996 score for the schools with data and for all the schools was +0.45

and +0.25 points (out of 100 points) for the flip-chart and comparison groups in 1997, respectively. In terms of standard deviations, this corresponds to average individual test differences of 0.6 and 0.4 percent of a standard deviation, respectively. In 1996, excluding the schools with missing 1997 data would therefore have lead to an overestimate of the relative scores of the flip-chart schools on the average individual test by 0.2 percent of a standard deviation. Assuming that any effect on the 1997 and 1998 results would be roughly of this magnitude, there is little reason to think that the inclusion of the missing schools would materially affect the results.

Conclusion

The analysis in this paper leads to two conclusions. First, prospective estimates of the impact of flip charts on children's performance on academic tests in Kenya show no impact at all of these charts on learning.[11]

Second, the analysis suggests that the most obvious retrospective regressions would have greatly overestimated the effect of a program providing flip charts on a large scale. More subtle retrospective analyses that compare test scores across subjects appear to reduce the bias significantly in the case of the flip chart intervention, which focused on particular subjects, but such techniques are not applicable for other inputs, such as school buildings or smaller pupil-teacher ratios, which affect all subjects, and could easily go astray in other contexts, given the ordinal nature of test score data.

There are two possible interpretations of the difference between the retrospective and prospective results. The schools in the retrospective sample that had flip charts may have differed from others in unobserved ways that raised their test scores independently of whether they had flip charts. Alternatively, the schools with flip charts may have differed from others in ways that would not have affected their test scores in the absence of flip charts, but which made flip charts particularly useful. Under either hypothesis, retrospective estimates would be a poor guide to the effects of a large-scale program to provide flip charts, but under the second hypothesis, they would be an appropriate measure of the effect of flip charts on those schools that choose to purchase them. The fact that test scores were higher in schools with flip charts, even in subjects where wall charts were not applicable, tends to support the first hypothesis, that schools with charts had higher test scores for reasons other than a causal effect of flip charts.

The omitted-variable bias in the retrospective estimates seems to lead to overestimation of treatment effects. The direction of bias makes sense in a developing country context, where compensatory programs are rare. If this result proves robust, it suggests that Hanushek's (1995) pessimistic conclusions about the effects of school inputs in developing countries based on retrospective studies may be strengthened, rather than weakened, by prospective studies.

[11] It is worth noting, however, that given that flip charts are very cheap, and that our standard errors are not tiny, we cannot rule out the possibility that flip charts are a good investment.

Table 1: Retrospective estimates of effect of four flip charts in Grades 6-8

Dependent variable: normalized 1998 test scores

	Mean (Std. Dev.)	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Specification						Diffs-in-diffs	
Random effects							
School		X	X	X	X	X	X
School*subject							X
Schools		83	79	79	79	79	79
Pupils		5,152	4,998	4,998	4,998	4,998	4,998
Grades included		6-8	6-8	6-8	6-8	6-8	6-8
Subjects included		Sc, Mat, HS	Sc, Mat, HS	Sc, Mat, HS	Sc, Mat, HS	All	All
Number of flip charts in school							
Number of charts (divided by four)	1.1	0.192***	0.194***	0.205***	0.076*	0.154***	0.157***
	(2.4)	(0.080)	(0.065)	(0.064)	(0.041)	(0.057)	(0.056)
Charts*Flip-chart subject (Science/Agr., Math, HS-BE)						0.049**	0.040*
						(0.021)	(0.024)
Other school inputs							
Indoor classroom	0.97		0.454**	0.399**	0.031	0.506***	0.503***
	(0.17)		(0.114)	(0.147)	(0.151)	(0.123)	(0.123)
Roof does not leak	0.98		0.161	0.063	-0.029	0.205	0.203
	(0.13)		(0.375)	(0.291)	(0.105)	(0.479)	(0.480)
Blackboard (1 = good cond., 0.5 = bad cond., 0 = none)	0.92		0.298	0.386*	0.038	0.294	0.293
	(0.18)		(0.188)	(0.228)	(0.065)	(0.180)	(0.180)
Textbooks per pupil	0.21		0.096*	0.119*	0.133***	0.063	0.089
	(0.24)		(0.051)	(0.069)	(0.028)	(0.047)	(0.065)
Desks per pupil	0.39		-0.018	0.098	-0.254***	0.246	0.247
	(0.16)		(0.339)	(0.418)	(0.098)	(0.327)	(0.327)
Teacher training level (0-6, 6 = high)	2.1		-0.039	-0.051	0.033*	-0.023	-0.023
	(0.8)		(0.033)	(0.045)	(0.018)	(0.033)	(0.032)
Class size	33			-0.001			
	(16)			(0.004)			
Pupil age	14.3			-0.069***			
	(2.0)			(0.009)			
Pupil's average score on non-wall chart subjects					0.770***		
					(0.009)		

Notes:

Regressions contain one observation per pupil for each subject. Columns 1-3 include flip-chart subjects only; columns 4 and 5 include all seven subjects.

All regressions contain school random effects, subject and grade fixed effects, and controls for the assistance received through the textbook and grant program. Column 5 includes school*subject random effects.

Since the data for these schools only provide information on the total number of science, math, and home science-business education (HS-BE) charts in the school, not the number in each subject, we estimate the average effect charts across all three subjects. Since the program

evaluated in the prospective study distributed four flip charts (2 Science, 1 Math, 1 HS-BE), we divide the number of charts variable by four to generate coefficients that are comparable with the retrospective analysis.
Standard errors are heteroskedasticity robust.
Statistical significance at the 10, 5, and 1 percent level is indicated by 1, 2, and 3 asterisks, respectively.

Table 2: Enrollment and Prior Year Performance of Busia and Teso Schools

	Entire district		Mean by study			Prospective study			
	Mean	**Std. Dev.**	**Prospective**	**Retrospective**	**Neither**	**Flip-chart**	**Comparison**	**Difference**	**T-stat**
Number of schools	337		178	100	59	89	89		
Enrollment									
1997 Grade 8 (Feb.)	22.3	11.9	23.3	18.9	25.6	24.3	22.4	+1.9	1.06
1996 Grade 8 (March)	20.7	12.4	21.4	17.4	24.6	22.3	20.5	+1.8	0.96
1995 Grade 8 (July)	21.0	11.5	21.7	18.2	23.8	22.7	20.8	+1.9	0.56
1997 Grade 7 (Feb.)	36.2	20.2	38.7	28.7	42.3	39.8	37.7	+2.1	0.69
1996 Grade 7 (March)	36.7	21.7	39.3	29.4	41.7	39.9	38.6	+1.3	0.40
1995 Grade 7 (July)	36.4	22.4	38.5	30.1	41.9	39.2	37.7	+1.5	0.87
Pre-intervention school-average test scores									
1996 Practice (March)	308.4	34.5	314.1	295.8	325.2	314.1	314.0	+0.1	0.02
1996 Practice (July)	304.3	37.8	312.1	288.9	325.3	312.1	312.0	+0.1	0.02

Notes:
Test scores are the sum of the raw scores which range from 0 to 100 on 7 subject exams.
T-test statistic is the same as the T-stat from a regression of school enrollment/test scores on a constant term and a treatment-comparison dummy variable.

Table 3: Sample size and summary statistics for the prospective analysis

		Students tested						Average test score			
		Received charts			Did not receive charts			(Percent correct on 4-choice test)			
Test	Grade	Both distr.	Busia	Teso	Both distr.	Busia	Teso	Charts	No charts	Difference	Std. Dev.
Jul-97	8	1,848	1,263	585	1,861	1,357	504	45.5	46.0	-0.5	12.5
Nov-97	8	1,790	1,262	528	1,843	1,420	423	48.7	49.6	-0.9	13.3
Jul-98	8	1,211	1,211	0	1,343	1,343	0	42.7	42.9	-0.3	11.2
Oct-98	8	1,737	1,206	531	1,891	1,370	521	49.5	49.5	0.0	13.0
Jul-98	7	1,734	1,734	0	1,798	1,798	0	37.6	37.5	+0.1	11.3
Jul-98	6	1,664	1,664	0	1,726	1,726	0	37.3	36.9	+0.4	11.4

Table 4: Prospective estimates of effect of flip charts – single subject multi-test regressions

Dependent variable: normalized test score

Subject	Past perf. Controls	Flip-chart school Coeff.	Flip-chart school Std. Error	Obs.
Flip-chart subjects				
Science/Agriculture	No	0.0005	0.0752	20,446
	Yes	-0.0007	0.0591	
Math	No	-0.0201	0.0600	20,441
	Yes	-0.0212	0.0486	
Health Science/Business Ed. (HSBE)	No	-0.0295	0.0728	20,434
	Yes	-0.0276	0.0559	
Geography/History/Civics/Religious Ed. (GHC)	No	0.0018	0.0714	20,450
	Yes	-0.0012	0.0553	
Non-flip chart subjects				
English	No	0.0038	0.0737	20,433
	Yes	-0.0100	0.0576	
KiSwahili	No	0.0110	0.0790	20,448
	Yes	0.0146	0.0737	
Arts/Crafts/Music (ACM)	No	-0.0679	0.0758	20,417
	Yes	-0.0723	0.0589	
Memo:				
Math and Science; grades 6 and 7 in 1998 only	No	0.0508	0.0828	13,836
	Yes	0.0534	0.0655	

Notes:

Regressions include school and school*year random effects and test fixed effects.

Past performance controls are controls for the school-average performance on the July 1996 practice exam.

Table 5: Prospective estimates of effect of flip charts – single test multi-subject regressions

Dependent variable: normalized test score

		Past perf.	4 Flip chart subjects		3 Non-flip chart subjects		
Test	Grade	controls	Coeff.	Std. Error	Coeff.	Std. Error	Obs.
All tests	6-8	No	-0.0117	0.0638	-0.0149	0.0649	143,069
		Yes	-0.0063	0.0484	-0.0144	0.0498	141,698
Jul-97	8	No	-0.0138	0.0716	-0.0388	0.0751	25,939
		Yes	-0.0347	0.0605	-0.0627	0.0644	25,827
Nov-97	8	No	-0.0474	0.0744	-0.0516	0.0758	25,418
		Yes	-0.0656	0.0601	-0.0700	0.0617	25,418
Jul-98	8	No	0.0135	0.0848	0.0102	0.0866	17,882
		Yes	0.0325	0.0718	0.0291	0.0739	17,791
Oct-98	8	No	-0.0018	0.0708	-0.0134	0.0722	25,396
		Yes	0.0145	0.0575	0.0043	0.0591	25,060
Jul-98	7	No	-0.0061	0.0910	-0.0029	0.0925	24,708
		Yes	0.0327	0.0669	0.0268	0.0690	24,288
Jul-98	6	No	0.0708	0.1005	0.0612	0.1019	23,726
		Yes	0.0579	0.0799	0.0485	0.0817	23,314

Notes:

Regressions include school, school*subject, and pupil random effects subject and test fixed effects.

Pupil random effects cannot be included when results are estimated for all tests due to computational constraints. For the single-test results, excluding pupil effects changes point estimates by no more than 0.0045 and standard errors by no more than 0.001.

Table 6: Prospective estimates of effect of flip charts – differences-in-differences estimator

Dependent variable: normalized test score

		Past perf.	FC school & FC subject		Flip-chart school		
Test	Grade	controls	Coeff.	Std. Error	Coeff.	Std. Error	Obs.
All tests	6-8	No	0.0031	0.0312	0.0117	0.0638	143,069
		Yes	0.0080	0.0308	0.0063	0.0484	141,698
Jul-97	8	No	0.0250	0.0594	-0.0138	0.0716	25,939
		Yes	0.0280	0.0581	-0.0347	0.0605	25,827
Nov-97	8	No	0.0042	0.0381	-0.0474	0.0744	25,418
		Yes	0.0044	0.0376	-0.0656	0.0601	25,418
Jul-98	8	No	0.0033	0.0464	-0.0135	0.0848	17,882
		Yes	0.0034	0.0468	0.0325	0.0718	17,791
Oct-98	8	No	0.0116	0.0367	-0.0018	0.0708	25,396
		Yes	0.0102	0.0368	0.0145	0.0575	25,060
Jul-98	7	No	-0.0032	0.0444	-0.0061	0.0910	24,708
		Yes	-0.0059	0.0442	0.0327	0.0669	24,288
Jul-98	6	No	0.0095	0.0448	0.0708	0.1005	23,726
		Yes	0.0094	0.0453	0.0579	0.0799	23,314

Notes:

Regressions include school, school*subject, and pupil random effects subject and test fixed effects.

Pupil random effects cannot be included when results are estimated for all tests due to computational constraints. For the single-test results, excluding pupil effects changes point estimates by no more than 0.0045 and standard errors by no more than 0.001.

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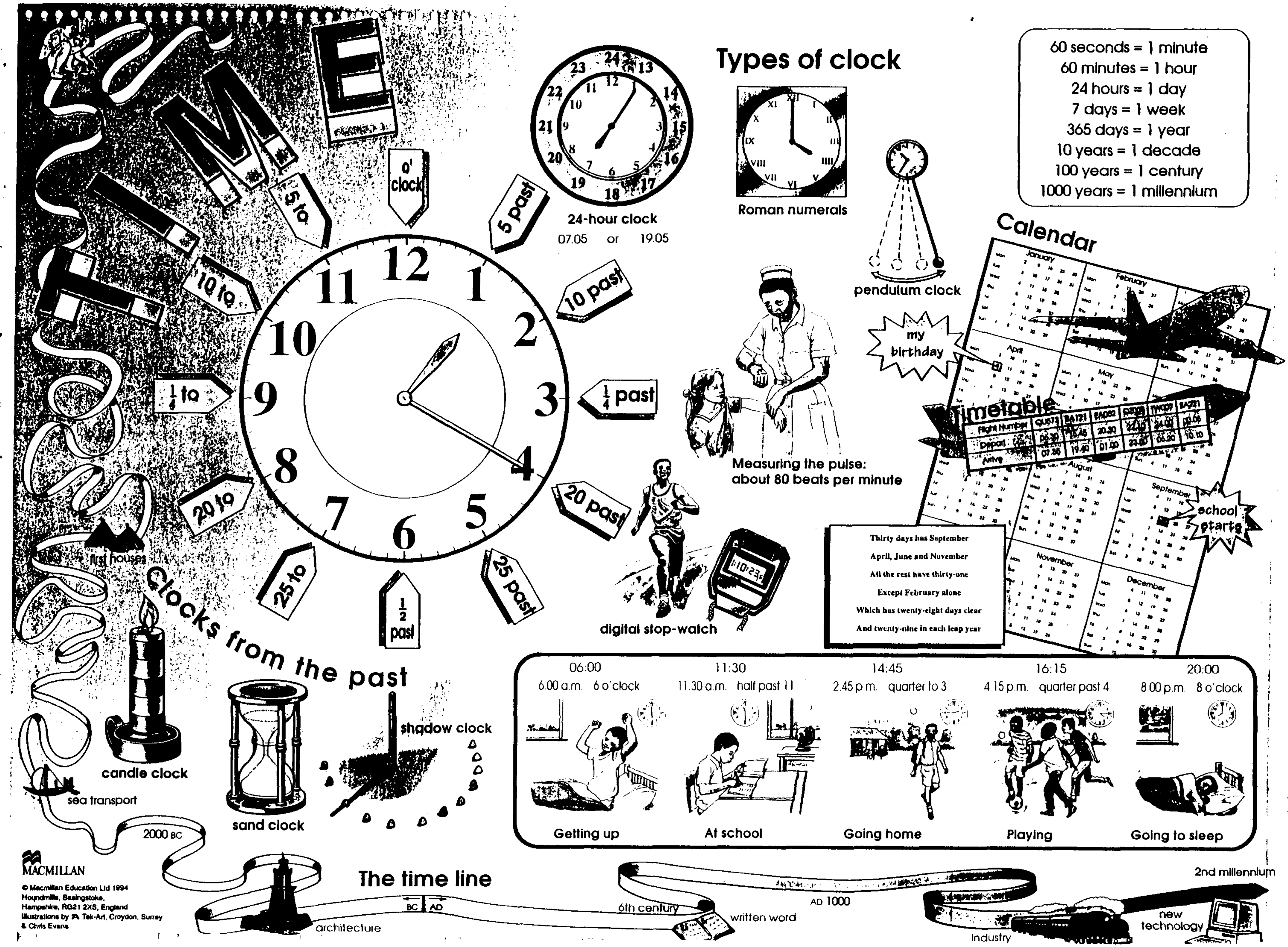
Macmillan Primary Wallcharts

Time	Fractions, decimals and percentages
Number	Formulae for shapes
Measures	Money
Shape	Patterns
Geometry	Algebra
Data	Investigations

MACMILLAN


TIME
o' clock
5 past
10 past
1/4 past
20 past
25 past
1/2 past
25 to
20 to
1/4 to
10 to
5 to
12
1
2
3
4
5
6
7
8
9
10
11
24-hour clock
07.05 or 19.05
Types of clock
Roman numerals
pendulum clock
60 seconds = 1 minute
60 minutes = 1 hour
24 hours = 1 day
7 days = 1 week
365 days = 1 year
10 years = 1 decade
100 years = 1 century
1000 years = 1 millennium
Calendar
my birthday
school starts
Timetable
Measuring the pulse: about 80 beats per minute
digital stop-watch
Thirty days has September
April, June and November
All the rest have thirty-one
Except February alone
Which has twenty-eight days clear
And twenty-nine in each leap year
Clocks from the past
candle clock
sand clock
shadow clock
06:00
6.00 a.m. 6 o'clock
Getting up
11:30
11.30 a.m. half past 11
At school
14:45
2.45 p.m. quarter to 3
Going home
16:15
4.15 p.m. quarter past 4
Playing
20:00
8.00 p.m. 8 o'clock
Going to sleep
first houses
sea transport
2000 BC
architecture
BC AD
The time line
6th century
written word
AD 1000
industry
2nd millennium
new technology
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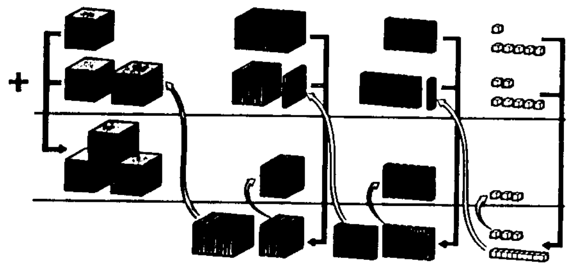
Hampshire, RG21 2XS, England
Illustrations by Tek-Art, Croydon, Surrey
& Chris Evans

NUMBER

Addition

1876 + 1597

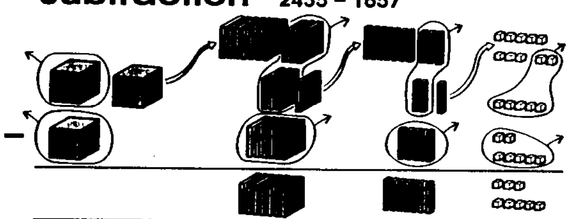


```
  1  8  7  6
+ 1  5  9  7
-------------
  3  4  7  3
```

6 add 7 is 13
write down 3, carry 1
7 add 9 add 1 is 17
write down 7, carry 1
8 add 5 add 1 is 14
write down 4, carry 1
1 add 1 add 1 is 3
write down 3

Subtraction

2435 – 1657

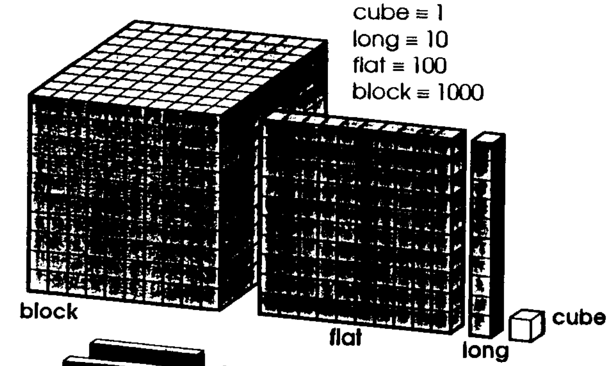


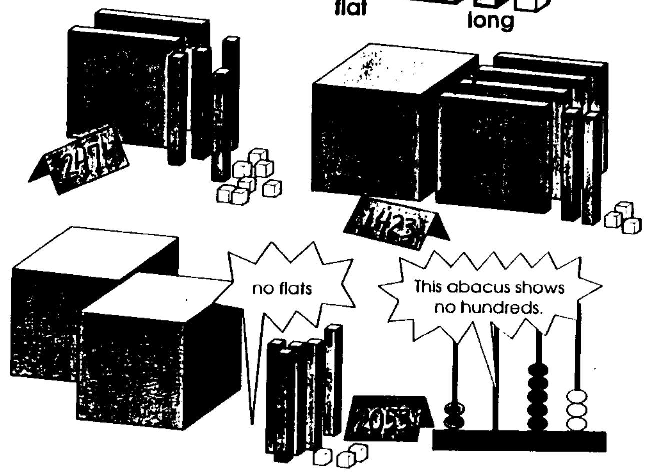
```
  2  4  3  5
- 1  6  5  7
-------------
     7  7  8
```

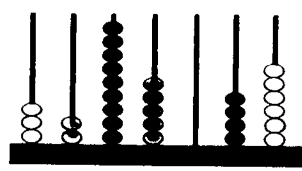
7 from 5, I can't, take from the tens
7 from 15 is 8, write down 8
5 from 2, I can't, take from the hundreds
5 from 12 is 7, write down 7
6 from 3, I can't, take from the thousands
6 from 13 is 7, write down 7
1 from 1 is 0, write down 0

Set of base-ten materials

cube ≡ 1
long ≡ 10
flat ≡ 100
block ≡ 1000





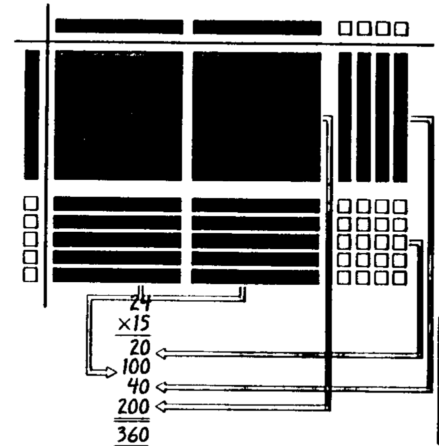


This abacus can show big numbers – 3 295 046.

Multiplication and division

24 x 15

360 ÷ 15




```
     24
15 ) 360
     30
      60
      60
       0
```

24 × 15 = 360
360 ÷ 15 = 24
360 ÷ 24 = 15

More

Less

EQUAL

15 > 10

10 < 15

210 > 146

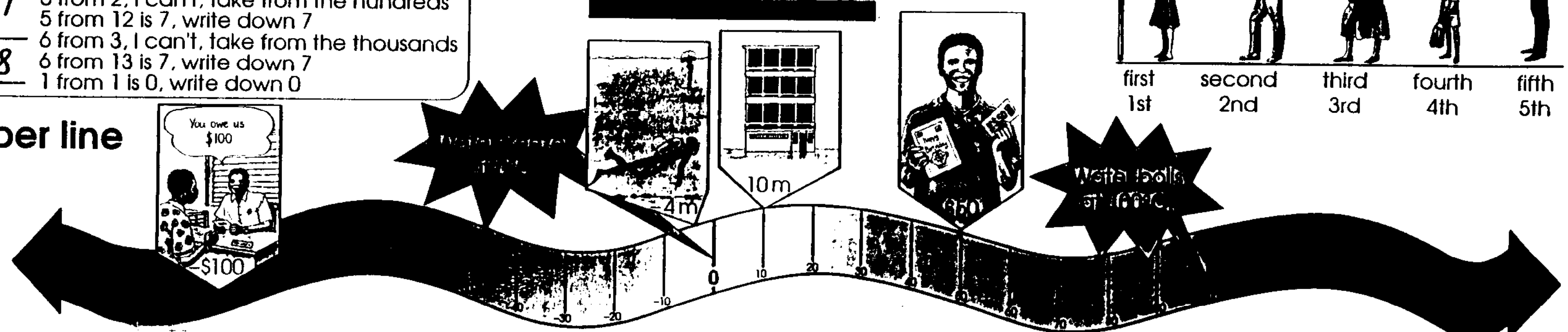
146 < 210

20 + 5 = 19 + 6
21 + 7 = 39 + 13
12 × 3 = 4 × 9

Order

first	second	third	fourth	fifth
1st	2nd	3rd	4th	5th

The number line



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Hampshire, RG21 2XS, England
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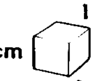
MEASURES

Capacity and volume

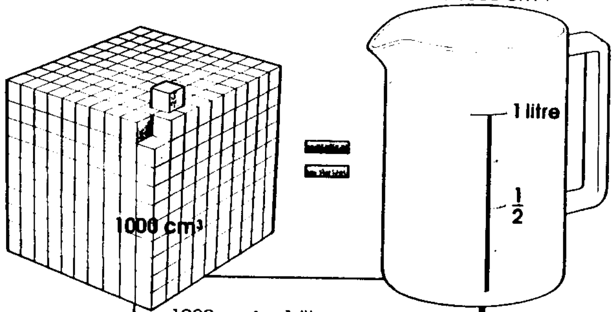
Volume is measured in cubic units.

The volume of this cube is

1 cm × 1 cm × 1 cm = 1 cm³.

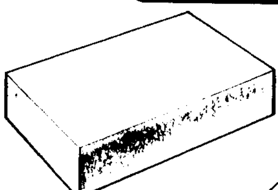


A litre is the amount of liquid with a volume of 1000 cm³.

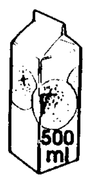


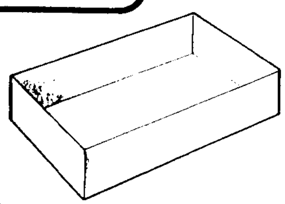
1000 cm³ = 1 litre

1000 millilitres (ml) = 1 litre (*l*)

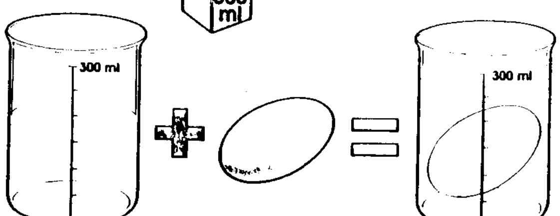


This block is a solid.
The amount of space
it takes up is the volume.



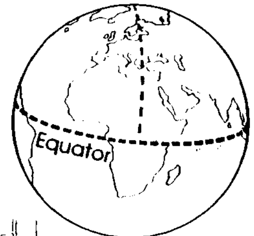


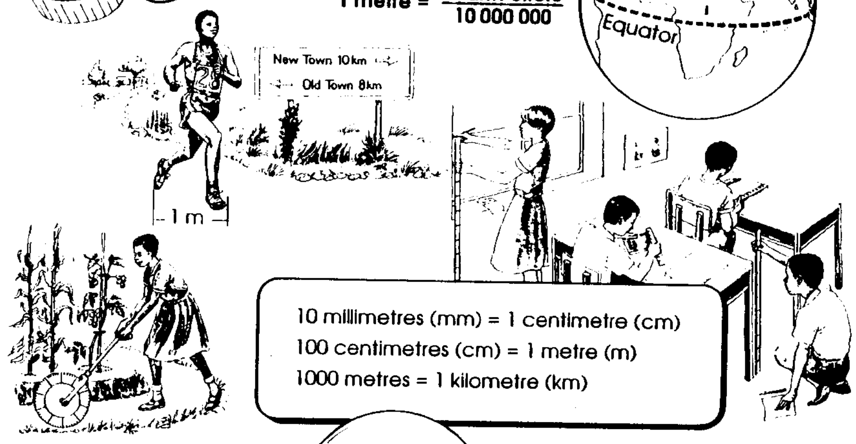
This box is a container.
The amount it will hold
is the capacity.



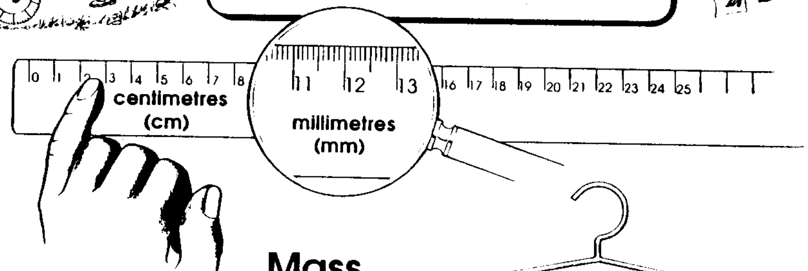
Length

1 metre = $\frac{\frac{1}{4}\text{ Earth circle}}{10\,000\,000}$



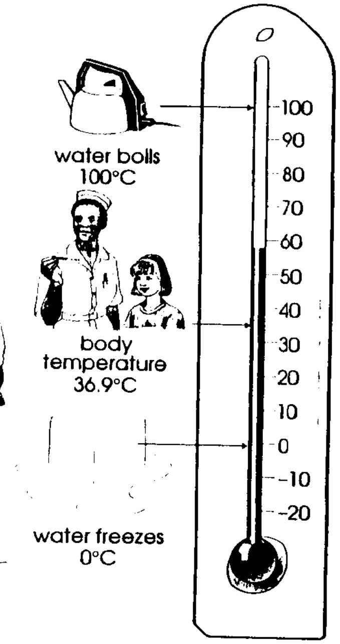


10 millimetres (mm) = 1 centimetre (cm)
100 centimetres (cm) = 1 metre (m)
1000 metres = 1 kilometre (km)

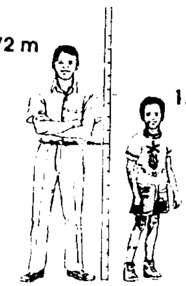


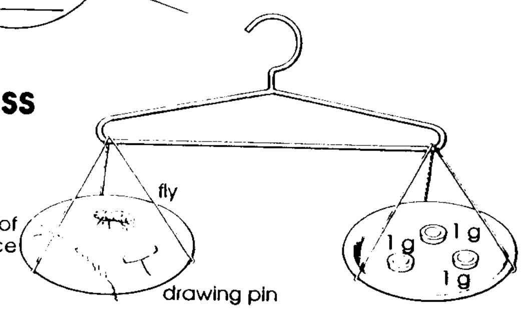
Temperature

Degrees Celsius (°C)

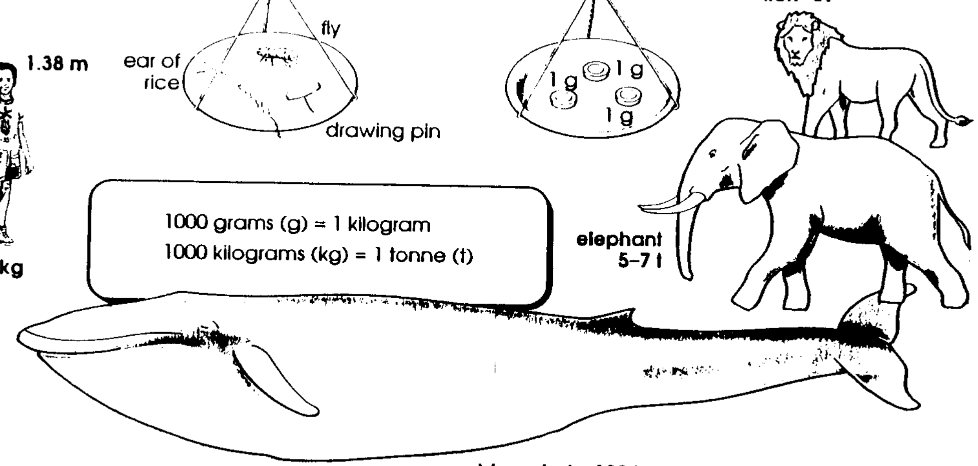


Mass





1000 grams (g) = 1 kilogram
1000 kilograms (kg) = 1 tonne (t)



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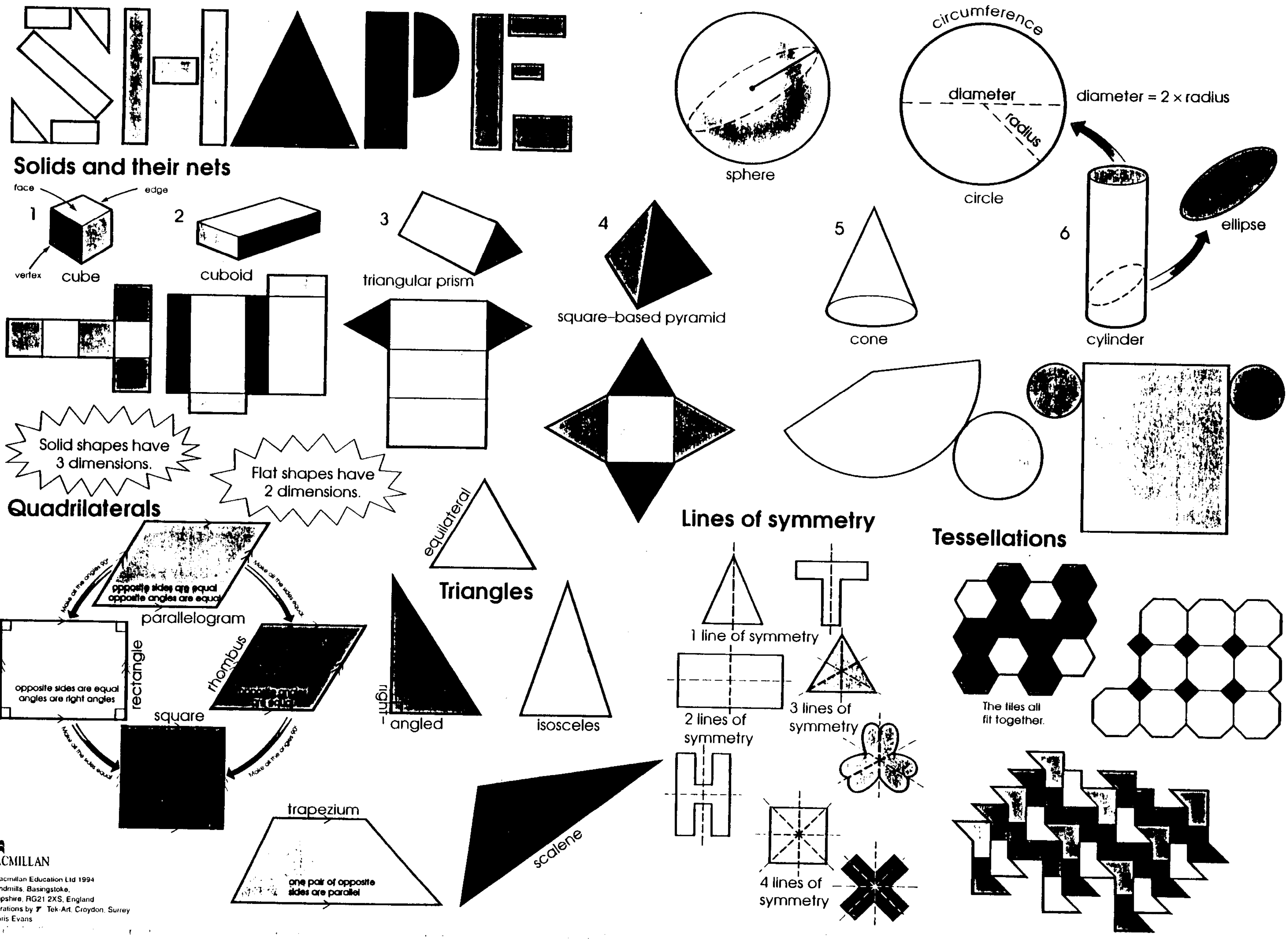

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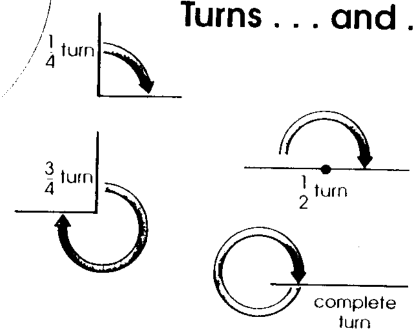
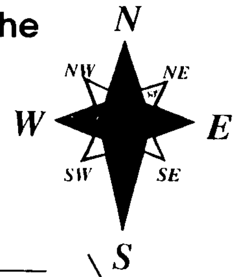
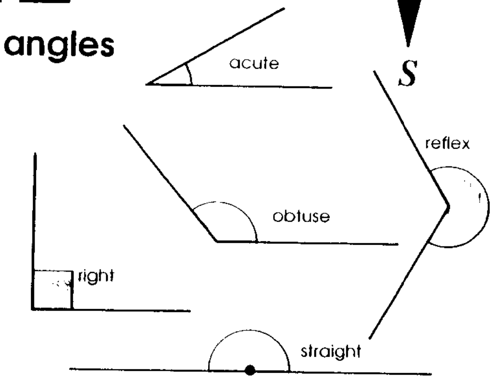
GEOMETRY

Turns . . . and . . . angles

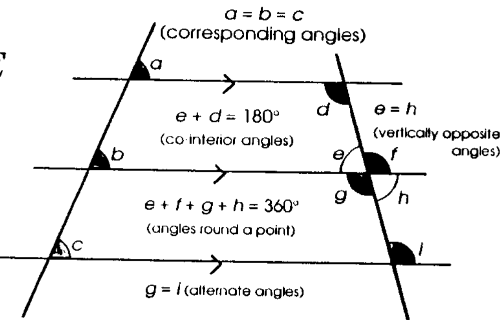


Points of the compass

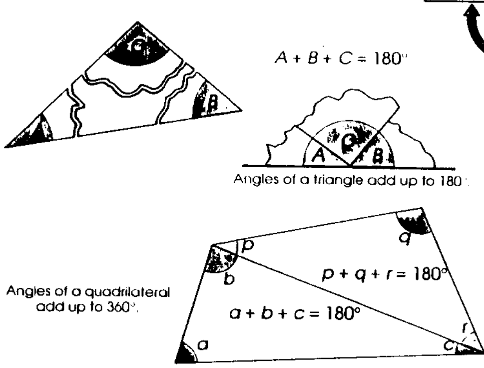




Angles and parallel lines

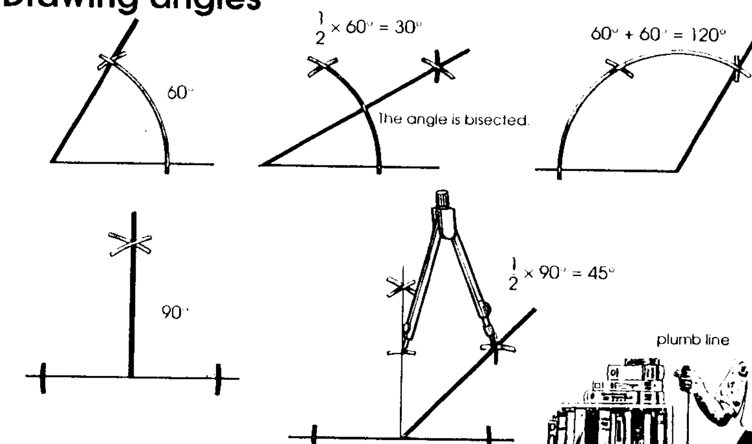


Sum of angles



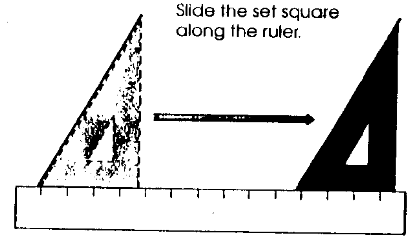
Angles of a quadrilateral add up to 360°.

Drawing angles

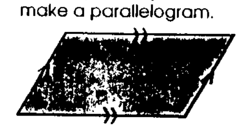


Drawing parallel lines

Slide the set square along the ruler.

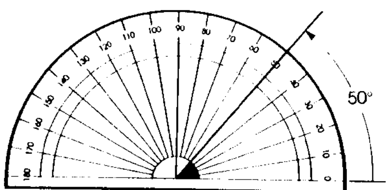


Draw 2 pairs of parallel lines to make a parallelogram.

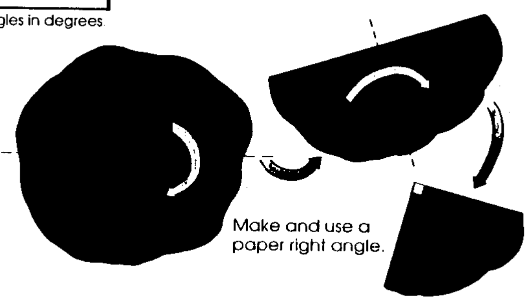


The arrows show the lines are parallel.

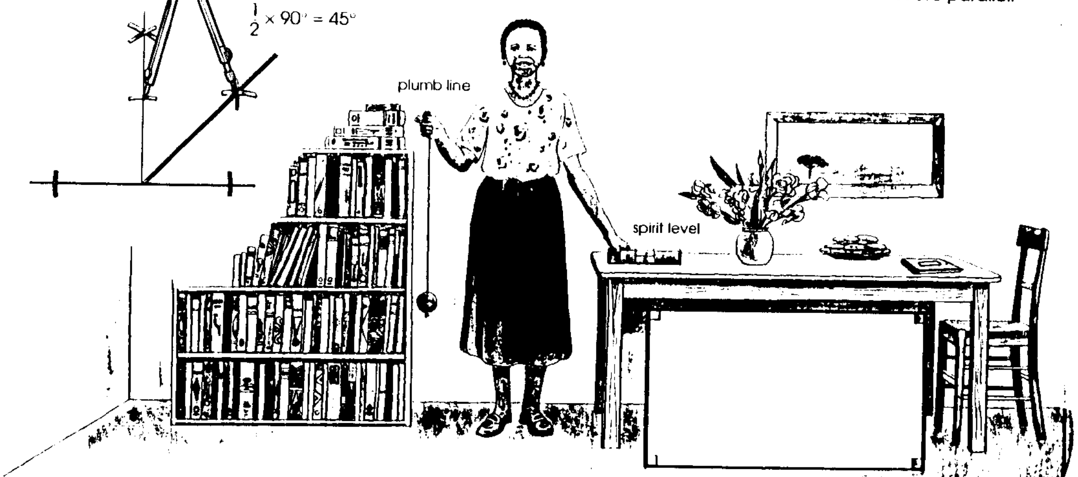
Measuring angles



Use a protractor to measure angles in degrees.



Make and use a paper right angle.



The sides of the rectangle are perpendicular to each other.

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DATA

Mean, median and mode

Mean height = $\frac{12}{8}$ = 1.50 m

Median height = $\frac{1.50 + 1.52}{2}$ = 1.51 m

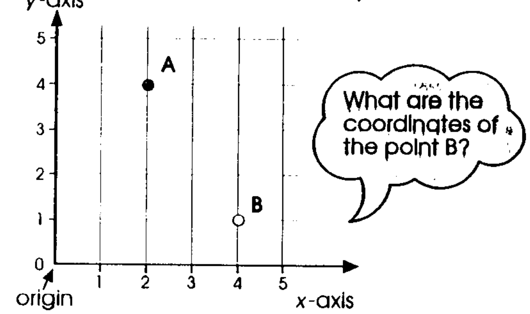
Mode = 1.52 m

Coordinates

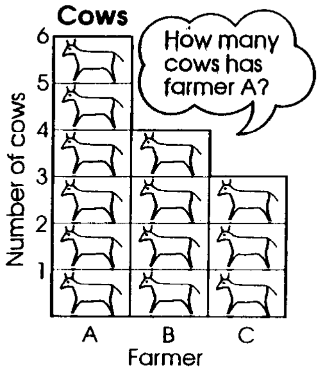
A is the point (2,4).

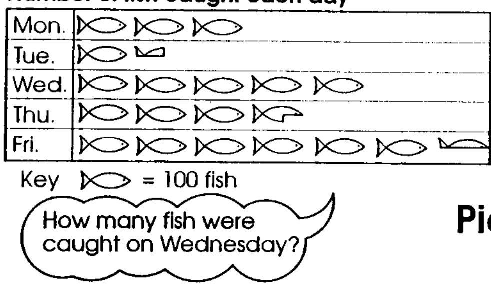
The x coordinate is 2.

The y coordinate is 4.

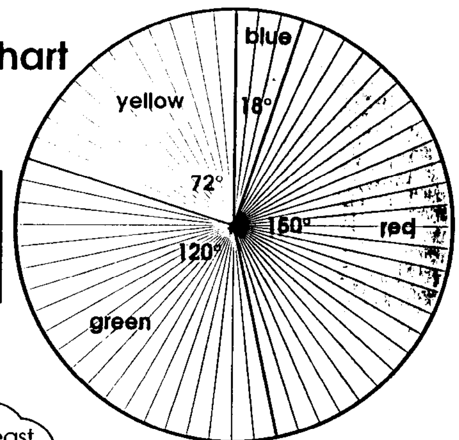


Picture graphs





Pie chart



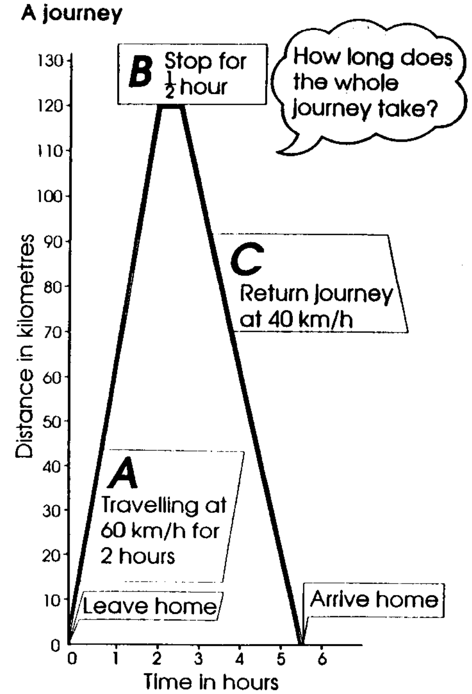
Favourite colours

Colour	red	green	yellow	blue	Total
Number of children	25	20	12	3	60
Degrees	150°	120°	72°	18°	360°

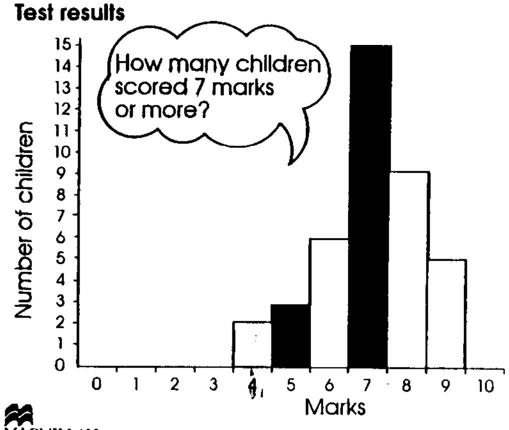
60 children = 360°

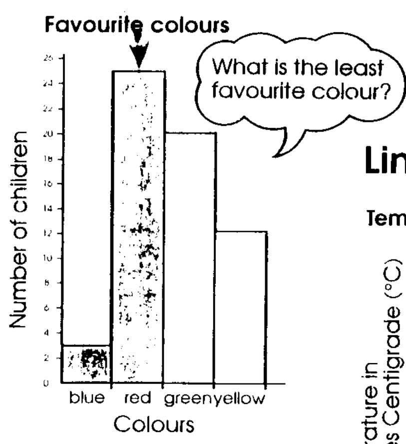
1 child = $\frac{360°}{60}$ = 6°

Travel graph



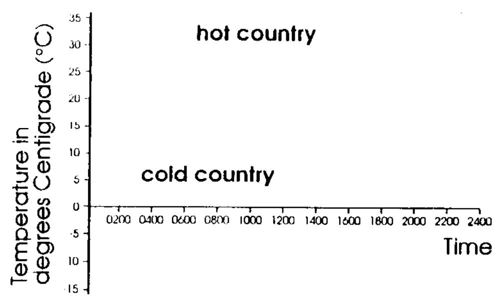
Bar charts





Mark	4	5	6	7	8	9	Total
Frequency	2	3	6	15	9	5	40

Line graph



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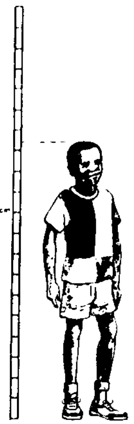
Houndmills, Basingstoke, Hampshire, RG21 2XS, England
Illustrations by Tek-Art, Croydon, Surrey & Chris Evans
Printed in Hong Kong

Fractions / DECIMALS + Percentages

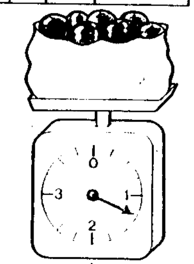
Decimals

Decimal	Units	$\frac{1}{10}$	$\frac{1}{100}$	Fraction
0.5 =	0	5		$= \frac{5}{10}$
1.25 =	1	2	5	$= 1\frac{25}{100}$
0.05 =	0	0	5	$= \frac{5}{100}$
3.61 =	3	6	1	$= 3\frac{61}{100}$



1.35 m = 1 metre and 35 centimetres

1.5 litres = 1 litre and 500 millilitres



1.25 kg = 1 kilogram and 250 grams

0:75

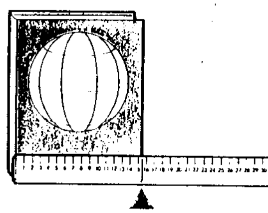
$\frac{3}{4} = 3 \div 4 = 0.75$

0:33

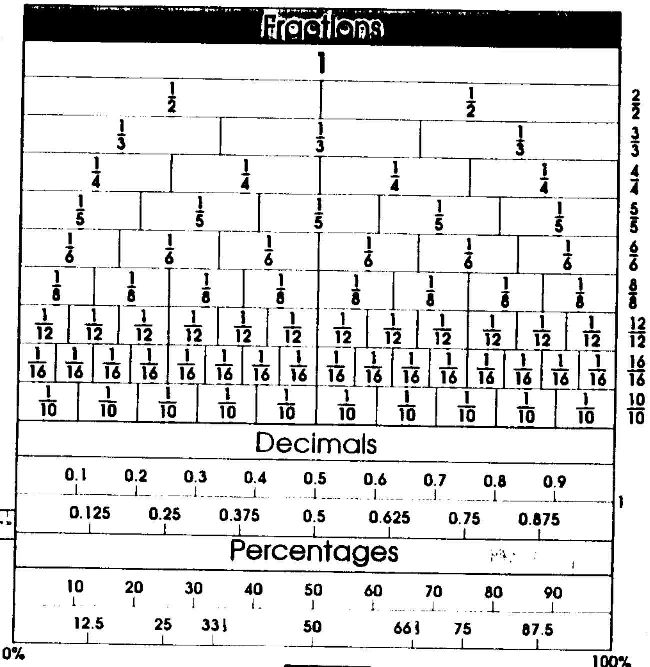
$\frac{1}{3} = 1 \div 3 = 0.3\dot{3}$

0:625

$\frac{5}{8} = 5 \div 8 = 0.625$

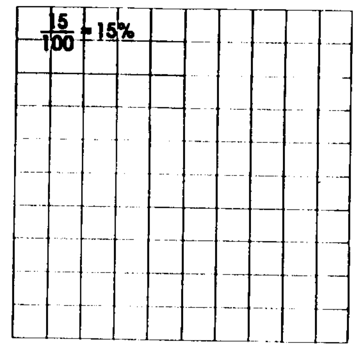


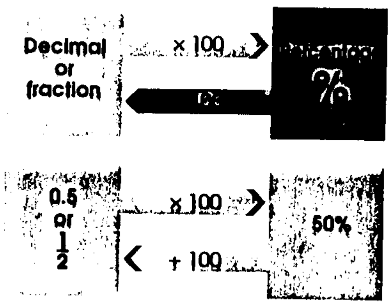
15.5 cm = 15 centimetres and 5 millimetres



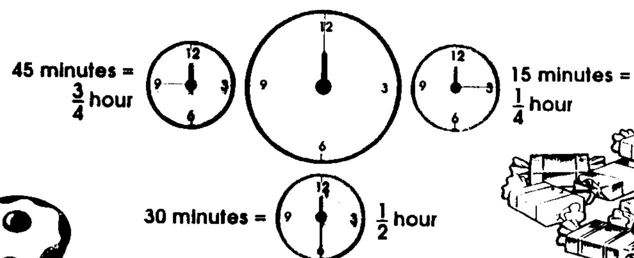
Percentages

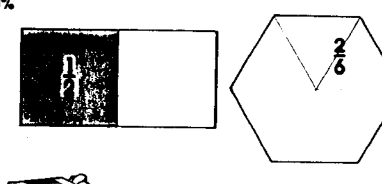
Percentage means part of a hundred.

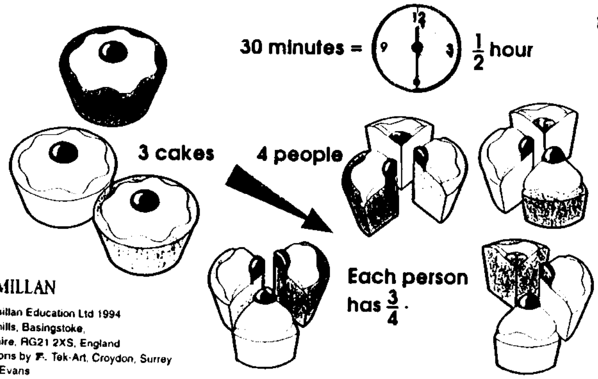


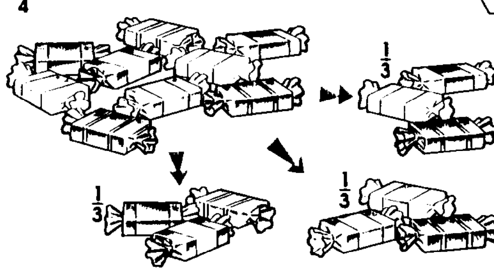


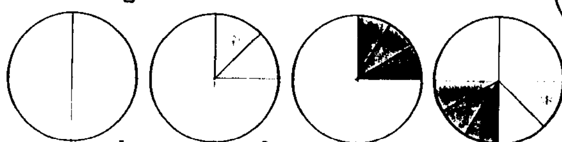
Fractions



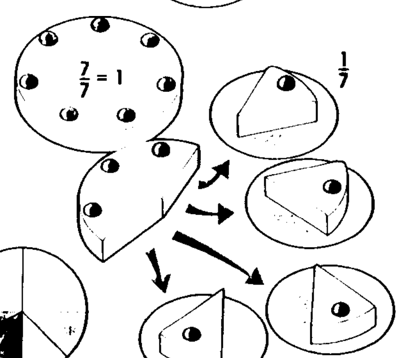








$\frac{1}{4} + \frac{2}{8} + \frac{3}{12} = \frac{3}{4}$



0.5 = $\frac{1}{2}$ = 50%

0.25 = $\frac{1}{4}$ = 25%

$0.3\dot{3}$ = $\frac{1}{3}$ = $33\frac{1}{3}$%

0.1 = $\frac{1}{10}$ = 10%

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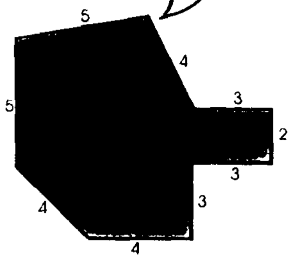
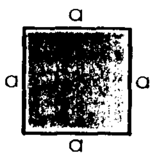
F-o+r×m÷u-l+ae for shapes

Perimeter

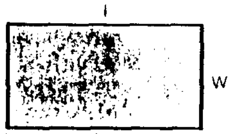
How far has the ant walked when it has gone all around the shape?



Perimeter
= 2 + 3 + 3 + 4 + 4 + 5 + 5 + 4 + 3
= 33 cm



Perimeter of a square is
a + a + a + a = 4a

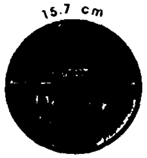


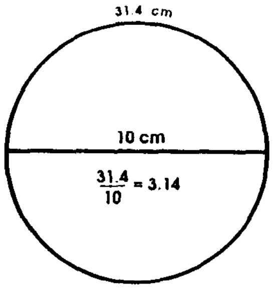
Perimeter of a rectangle is
l + w + l + w = 2(l + w)

The perimeter of a circle is called the circumference.

$$\frac{\text{Circumference}}{\text{Diameter}} = \frac{22}{7} \text{ or } 3.14 = \pi$$

Circumference = π x Diameter

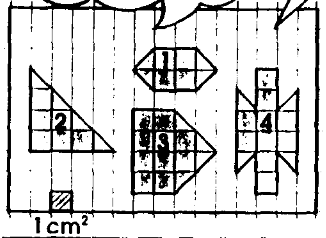


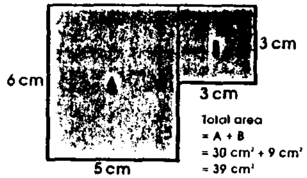


Area

How many unit squares are there in each shape?

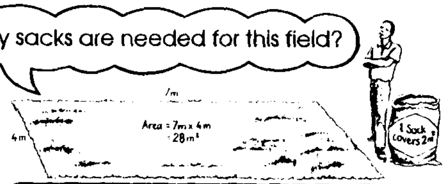
Remember to count the half squares as well.

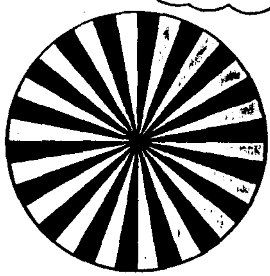




SHAPE		FORMULAE AREA
Square		$a \times a = a^2$
Rectangle		l x w
Triangle		$\frac{1}{2}$ x b x h
Parallelogram		b x h

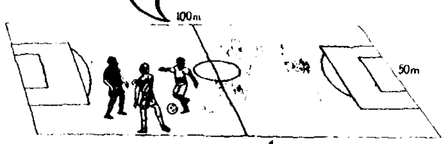
How many sacks are needed for this field?





Area of a circle is π x r²

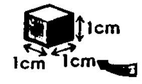
What is the area of this football pitch?



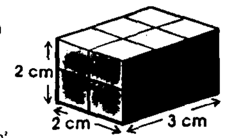
How far is it if you run all around the pitch?

l = length
h = height
w = width
b = base
r = radius

Volume and surface area

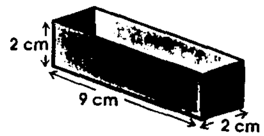


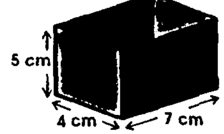
Each side of this cube measures 1 cm.
This is 1 cm³.

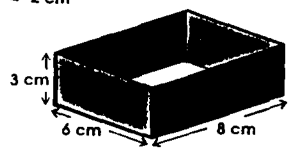


Volume of this cuboid is
2 x 2 x 3 = 12 cm³
12 1cm cubes will fit into this cuboid.

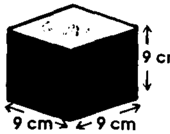
How many 1 cm cubes will fit into these cuboids ?



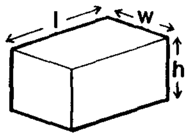




SHAPE		FORMULAE Volume	Surface Area
cube		$a \times a \times a = a^3$	$a^2 + a^2 + a^2 + a^2 + a^2 + a^2 = 6a^2$
cuboid		l x w x h	2 x l x w + 2 x l x h + 2 x w x h = 2(lw + lh + wh)
cylinder		$\pi r^2 h$	$2\pi r (h + r)$

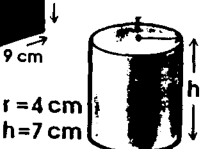


Volume = 9 x 9 x 9 = 729 cm³



l = 15 cm
h = 3 cm
w = 4 cm

Volume = 15 x 4 x 3 = 180 cm³



r = 4 cm
h = 7 cm

Volume = $\frac{22}{7}$ x 4² x 7 = 352 cm³

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Illustrations by Tek-Art. Croydon Surrey
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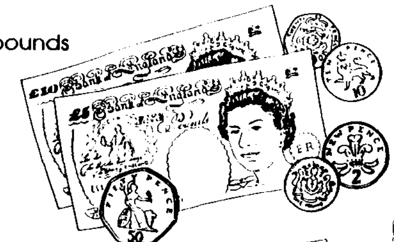
Currency

The most common international currencies are:

pounds



dollars

Other countries have their own currencies.

Hire Purchase

Shopping

sale

10% discount

Compare the prices in your local store with the prices in the supermarket.

Wages

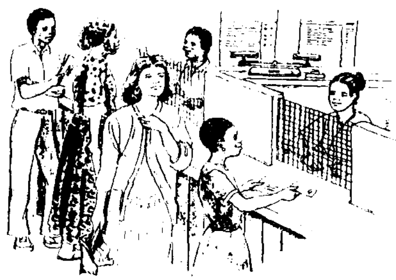
This woman is paid per piece of work completed.

This person is paid a salary.

This man is paid per day's work done.

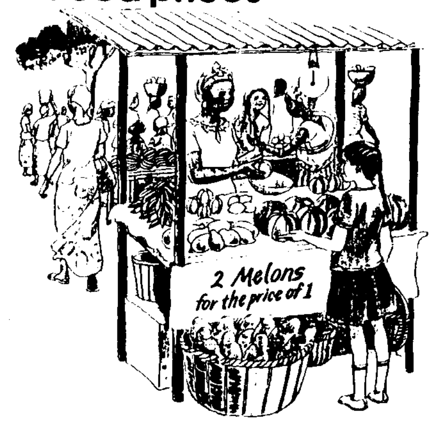
Post Office

How much does it cost to post a letter to the next town?



How much does it cost to post a letter to America?

Food prices



When you spend $150 you get 5% discount. How much do you save?

Discounts and profits

10% discount = $\frac{10}{100}$ x selling price

Sale price = price - discount

PROFIT = Selling price - Buying price

% PROFIT = $\frac{\text{Profit}}{\text{Buying price}}$ x 100

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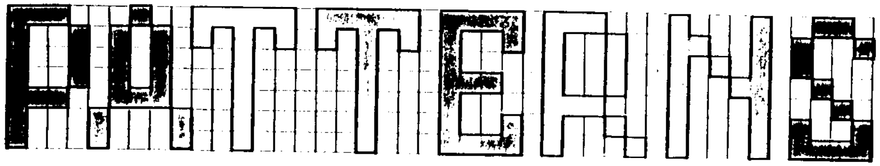
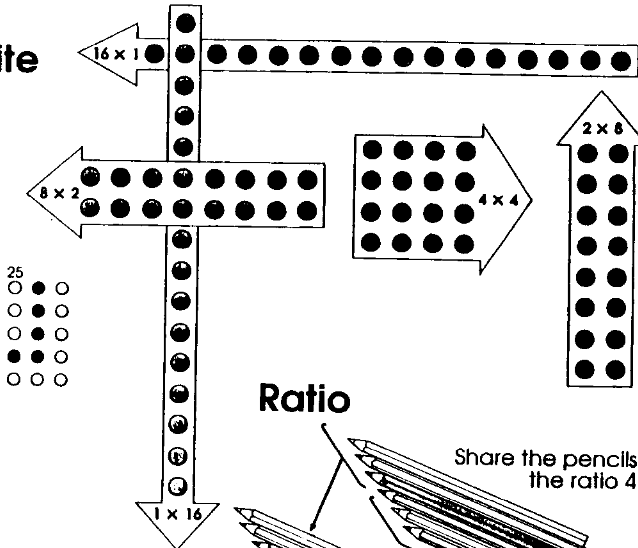


Composite numbers

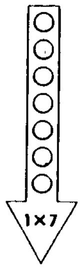


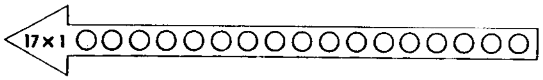
Prime numbers

A prime number can only be divided by itself and 1.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50

Key
÷ 2
÷ 3
÷ 5
÷ 7
Prime number





Multiples

Multiples of 8

1	2	3	4	5	6	7	**8**	9	10
11	12	13	14	15	**16**	17	18	19	20
21	22	23	**24**	25	26	27	28	29	30
31	**32**	33	34	35	36	37	38	39	**40**
41	42	43	44	45	46	47	**48**	49	50
51	52	53	54	55	**56**	57	58	59	60
61	62	63	**64**	65	66	67	68	69	70
71	**72**	73	74	75	76	77	78	79	**80**
81	82	83	84	85	86	87	**88**	89	90
91	92	93	94	95	**96**	97	98	99	100

Multiples of 3

1	2	**3**	4	5	**6**	7
8	**9**	10	11	**12**	13	14
15	16	17	**18**	19	20	**21**
22	23	**24**	25	26	**27**	28
29	**30**	31	32	**33**	34	35
36	37	38	**39**	40	41	**42**
43	44	**45**	46	47	**48**	49

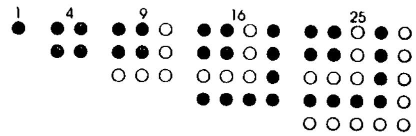
Multiples of 6

1	2	3	4	5	**6**	7
8	9	10	11	**12**	13	14
15	16	17	**18**	19	20	21
22	23	**24**	25	26	27	28
29	**30**	31	32	33	34	35
36	37	38	39	40	41	**42**
43	44	45	46	47	**48**	49
50	51	52	53	**54**	55	56
57	58	59	**60**	61	62	63
64	65	**66**	67	68	69	70
71	**72**	73	74	75	76	77

Multiples of 9

1	2	3	4	5	6	7	8	**9**	10
11							**18**		20
21						**27**			30
31					**36**				40
41				**45**					50
51			**54**						60
61		**63**							70
71	**72**								80
81									**90**
91	92	93	94	95	96	97	98	**99**	100

Square numbers



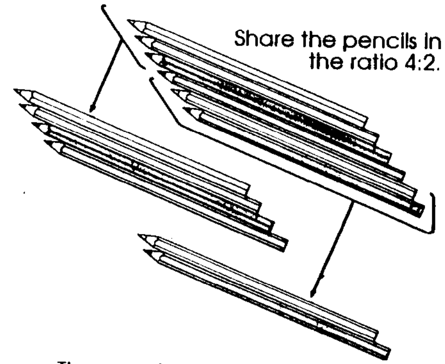
$5 \times 5 = 25 = 5^2$

$1 + 3 + 5 + 7 + 9 = 25 = 5^2$

$\sqrt{25} = 5$

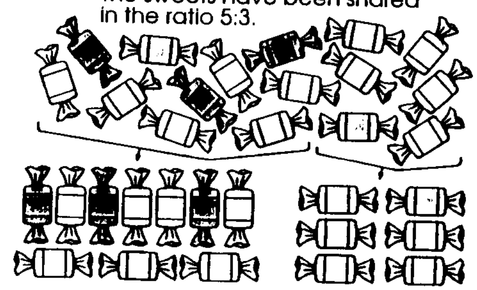
×	1	2	3	4	5	6	7	8	9	10
1	**1**	2	3	4	5	6	7	8	9	10
2	2	**4**	6	8	10	12	14	16	18	20
3	3	6	**9**	12	15	18	21	24	27	30
4	4	8	12	**16**	20	24	28	32	36	40
5	5	10	15	20	**25**	30	35	40	45	50
6	6	12	18	24	30	**36**	42	48	54	60
7	7	14	21	28	35	42	**49**	56	63	70
8	8	16	24	32	48	40	56	**64**	72	80
9	9	18	27	36	45	54	63	72	**81**	90
10	10	20	30	40	50	60	70	80	90	**100**

Ratio



Share the pencils in the ratio 4:2.

The sweets have been shared in the ratio 5:3.



Odd or even

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50

Odd

Even

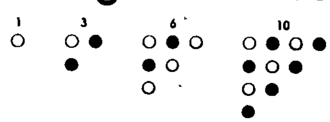
2 + 4 = 6
2 + 4 + 6 = 12
2 + 4 + 6 + 8 = 20

Are the answers always even?

1 + 3 = 4
1 + 3 + 5 = 9
1 + 3 + 5 + 7 = 16

Will the next number be odd or even?

Triangular numbers



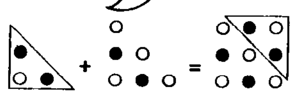
Can you find the next 3 triangular numbers?

$1 + 3 = 4 = 2^2$

$3 + 6 = 9 = 3^2$

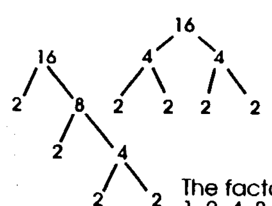
$6 + 10 = 16 = 4^2$

$10 + 15 = 25 = 5^2$

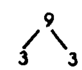


$3 + 6 = 9 = 3^2$

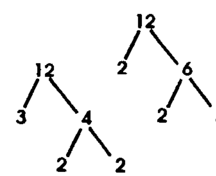
Factors



The factors of 16 are 1, 2, 4, 8 and 16.



The factors of 9 are 1, 3 and 9.



The factors of 12 are 1, 2, 3, 4, 6 and 12.

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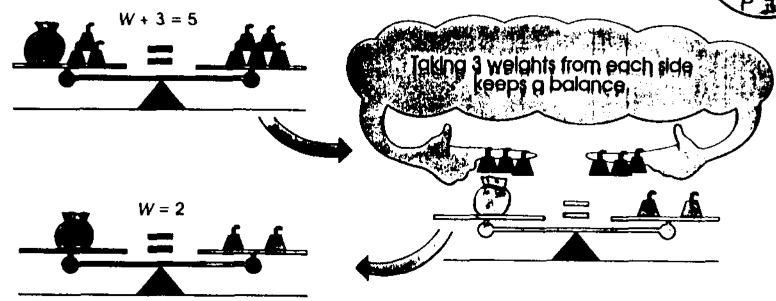
Illustrations by ✗ Tek-Art, Croydon, Surrey & Chris Evans

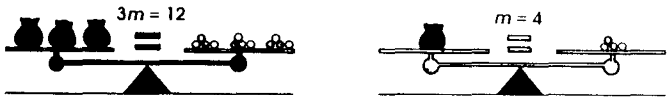
Algebra

Equations

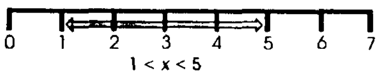
W = number of weights in each bag

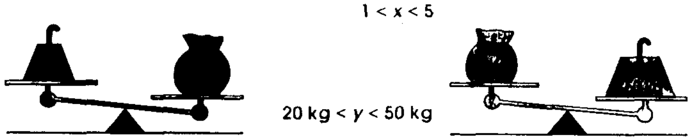


m = number of marbles in each bag



Inequality





20 kg $< y <$ 50 kg

Formulae

In the school dining room, the tables are arranged in a row.

The number of tables depends on how many pupils want to have dinner.

t = number of tables c = number of chairs

	t	c
	1	$6 = 4 \times 1 + 2$
	2	$10 = 4 \times 2 + 2$
	3	$14 = 4 \times 3 + 2$
	4	$18 = 4 \times 4 + 2$

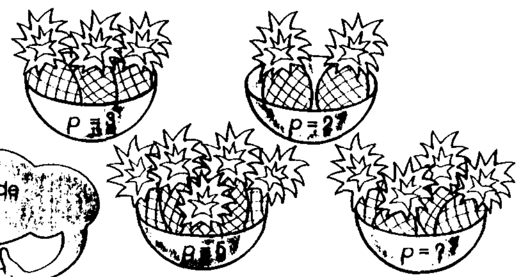
The formula linking c and t is:
$c = 4t + 2$

If there are 6 tables, how many chairs are there?
$c = 4 \times 6 + 2 = 26$

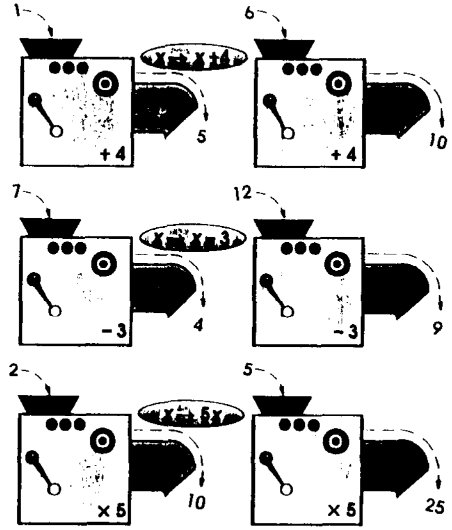
If there are 10 tables, how many pupils are going to have school dinner?

Letters for numbers

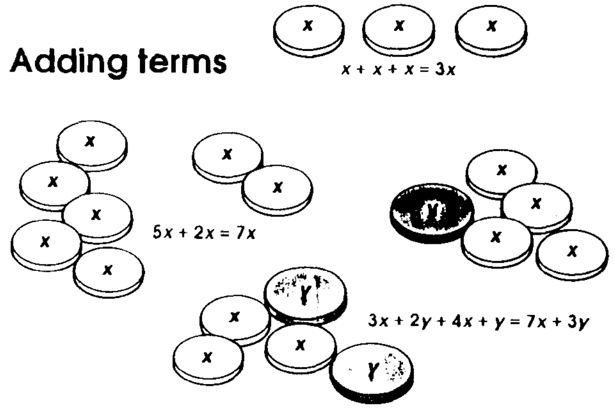
p = number of pineapples



Function machines

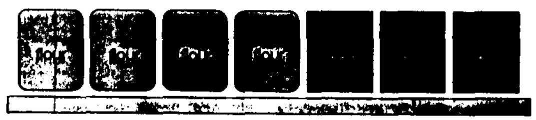


Adding terms



Relationships

On a kitchen shelf there is space for 7 packets.
Flour and sugar packets are the same size.
The shelf is always full.



The packets can be arranged in lots of ways.

f is the number of flour bags
s is the number of sugar bags

	f	s
	4	3
	0	7
	2	5

We write: $f + s = 7$

If there are 6 bags of flour on the shelf, how many bags of sugar are there?

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Illustrations by Tek-Art, Croydon, Surrey & Chris Evans

INVESTIGATIONS

Sequences

Pascal's triangle

Counting numbers

Triangular numbers

1

1 1

1 2 1

1 3 3 1

1 4 6 4 1

1 5 10 10 5 1

1 6 15 20 15 6 1

1 7 21 35 35 21 7 1

Can you work out the next line?

Fibonacci sequence

1, 1, 2, 3, 5, 8, 13, 21, . . .

1 + 1 = 2

[redacted]

2 + 3 = 5

3 + 5 = 8

5 + 8 = 13

8 + 13 = 21

Can you find the next five numbers?

Can you add the numbers on Pascal's triangle to find the Fibonacci sequence?

Can you find the next six numbers in the following sequences?

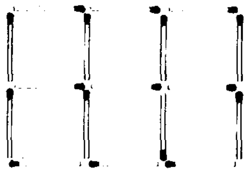
1, 2, 4, 8, 16, __, __, __, __, __, __

1, 4, 7, 10, __, __, __, __, __, __

100, 96, 92, 88, __, __, __, __, __, __

Try making some number sequences for yourself.

Puzzles

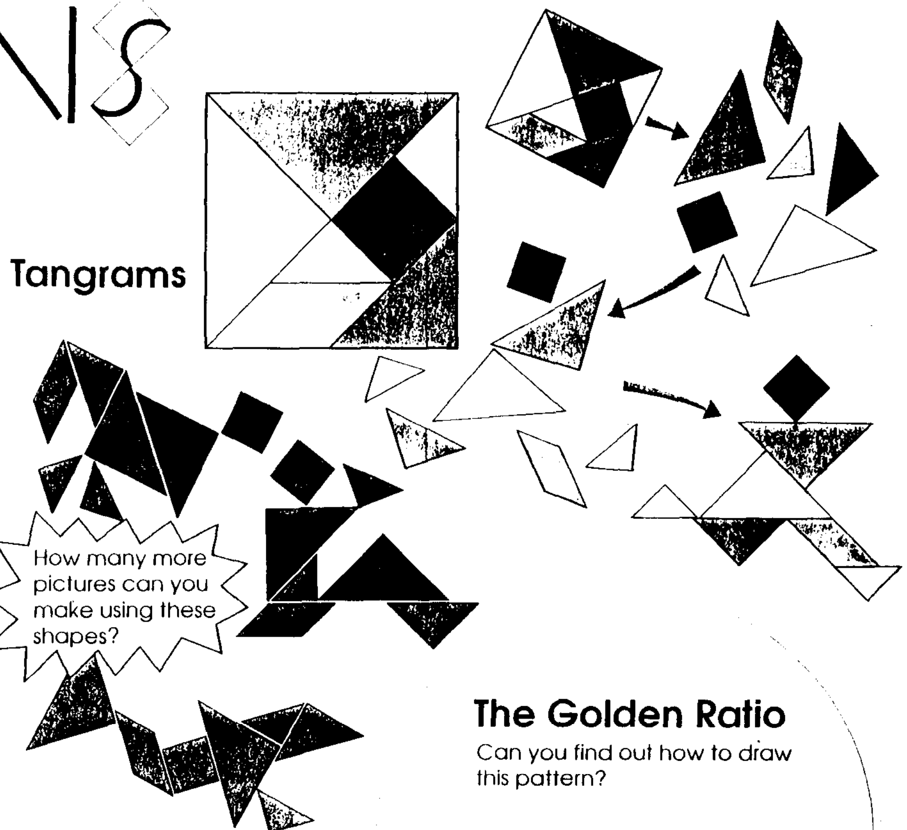


Make this shape using matchsticks.

Can you take away 5 matches and leave only 3 squares of the same size?

Try making your own matchstick puzzle.

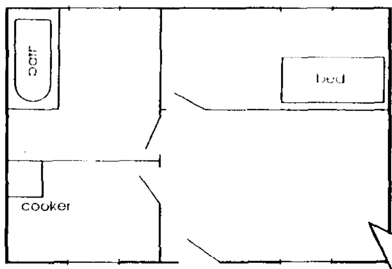
Tangrams



How many more pictures can you make using these shapes?

Scale drawing

Here is a plan of a house.



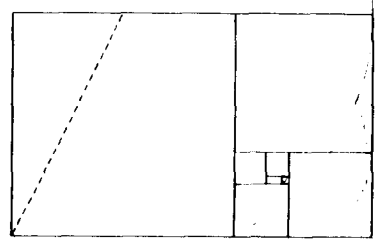
Scale: 2 cm = 1 m

The kitchen measures 3 m × 2 m. How big are the other rooms?

Draw a plan of your house and your classroom.

The Golden Ratio

Can you find out how to draw this pattern?



Magic squares

This is a magic square. Each line adds up to 15.

6	7	2
1	5	9
8	3	4

15 15 15

Here are some more magic squares which have numbers missing. Can you put in the missing numbers? (Add the complete line first to find the total.)

	3	4
	5	
6	7	

5		3
9	2	7

7		
	6	
3		5

Durer's magic square

Each line totals 34.

34

16	3	2	13
5	10	11	8
9	6	7	12
4	15	14	1

34

The centre 4 squares total 34.

The numbers on the coloured lines total 34.

Can you make your own magic square? (Try using fractions and decimals.)

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