# AN EXPERIMENT IN THE USE OF GAMES IN THE TEACHING OF MENTAL ARITHMETIC

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## INTRODUCTION

Following a voluntary pilot test in 1997, a statutory mental arithmetic test was introduced into the Key Stage 3 SATS examinations during 1998 for all pupils in England and Wales working at National Curriculum level three or above. This examination had a weighting of twenty percent. Although there are concerns about various aspects of these mental arithmetic tests they are to continue, in more or less the same form, for 1999.

I currently teach a year nine group of middle to low attainers in mathematics and have been concerned about their preparation for this mental arithmetic test. Throughout the academic year we have spent time each week on mental arithmetic, but generally in the form of a short test. Initially this seemed beneficial but as time has passed it seems to have polarised the group into those who enjoy mental arithmetic and are keen to do well and those who struggle with it and have not been motivated by the test situation. I was therefore keen to try a new approach, and decided that using games would be a contrast to the approach I had used so far. I decided to focus on one particular topic, and this was the relationships between fractions, decimals and percentages and the use of them in simple calculations. I used a simple diagnostic test at both the start and the conclusion of the experiment to evaluate the effectiveness of the two games that I had chosen to use with the class.

I will start by briefly looking at the research on the difficulties children encounter with relationships between fractions, decimals and percentages and then move onto research that has been conducted into the use of games in the classroom and in particular their use for mental arithmetic. The results of the experiment are presented next. I will finish with a summary of the results and their significance together with my personal reflections on the experiment.

## REVIEW OF LITERATURE

What are the problems with decimals, fractions and percentages?
The problems my class have had with fractions, decimals and percentages are nothing new. Other studies have recognised the problems children have with these topics, and I quote here examples from two such studies. The results of the sixth National Assessment of Educational Progress (NAEP) conducted in 1992 highlighted the difficulties students have in tasks that have mixed fraction and decimal notation. One particular item illustrates this clearly:

Of the following, which is closest in value to 0.52?

A. $\frac{1}{50}$    B. $\frac{1}{5}$    C. $\frac{1}{4}$    D. $\frac{1}{3}$    E. $\frac{1}{2}$

Only 51% of eighth grade students (13 years old) chose 1/2 as the fraction closest to 0.52, with 29% thinking that 1/50 was closest. The authors felt that the particularly low performance on this task was due to difficulties students have in tasks that have mixed fraction and decimal notation. These two items from the Concepts in Secondary Mathematics and Science (CSMS) study reported in Hart (1981) highlight two other problems in this area.

Multiply by ten: 5.13 -->

| Age | 13 | 14 |
|---|---|---|
| Facility | 42% | 58% |

Four tenths is the same as
............ hundredths

| Age | 13 | 14 |
|---|---|---|
| Facility | 31% | 42% |

Hart and the CSMS team (1981) noted
It is above all clear that the learning of whole numbers and decimals is not
just a matter of recalling some place-names and a few rules of computation,
as it appears to be from the textbooks. ...
Instead, it involves internalising a whole chain of relationships and connections, some within the place structure itself (e.g. 0.9 is equivalent to 0.90) some
linking to other concepts like those of fractions (e.g. the notion of one
hundredth and its relationship to one tenth), some visual correspondences
and some connecting applications to the real world. (page 64)
Having recognised that these problems are widespread I now consider the advantages and disadvantages of using games to help my class cope with these topics in mental arithmetic tests.

What is a game?
There are differing definitions of mathematical games in the literature. In the context of this experiment I will use the definition offered by Ainley (1988),
The most effective mathematical games are those in which the structure and
rules of the game are based on mathematical ideas, and where winning the
game is directly related to understanding this mathematics. (page 241)

Why play games?
Hatch (1998b) classifies the intrinsic advantages of games under three headings:

1. Learning
2. Ways of working
3. Pupil experience

and I will use her structure to examine the literature available on games.

## 1. Learning
Much of mathematics teaching revolves around giving children practice in newly acquired skills and of reinforcing and developing skills. Games provide a way of taking the drudgery out of the practice of skills, and indeed of making the practice more effective. Hatch points out that 'a game can generate an unreasonable amount of practice' (page 3). A game that is enjoyed can deliver far more practice than a set of examples and she claims that the level of repetition would be unreasonable in some games if they did not have some pleasurable outcomes. A team of American researchers Bright, Harvey and Wheeler (1979) have carried out many studies of the use of games to teach mathematics. Two of the studies involved the use of games to reinforce basic multiplication and division facts with single digit factors. 14 classes of 9, 10 and 11 year olds in 1976 and 10 classes of 10 and 11 year olds in 1977 played the games for 15 minutes daily for a total of 7 days. Gains in test performances showed that the games treatment was an effective way to retrain and reinforce children's skills with basic number facts. A further study by Bright and Harvey (1982) involved supplementing regular instruction on decimal fractions with the playing of a game. Some students in the class played the game regularly in 20 minute sessions over a period of a few weeks the remainder of the class only received regular instruction. A test monitoring improvement showed that all the children improved over the few weeks and progress for those children playing one of the games was significantly better, with another of the games they concluded that there seemed to be no added effect due to game playing. Ernest (1986) claims that the success of mathematics teaching depends to a large extent on the active involvement of the learner. Playing games demands involvement. Games cannot be played passively they have to be actively involved, for this reason psychologists including Piaget, Bruner and Dienes suggest games have a very important part to play in learning, particularly in the learning of mathematics. Dienes (1963) even suggests that all mathematics teaching should begin with games.

## 2. Ways of working

Paragraph 243 of the Cockcroft Report (1982) that stressed that children need to discuss mathematics as well as learning it. There are many forms of discussion built into the playing of games. The simplest is when a player explains to another why a particular move is, or is not, legitimate. There are also occasions when peer tuition emerges, notably in co-operative games. Hatch (1998b) suggests that this can be encouraged in many games by using pairs of pupils working together as a 'single' player. A lot of discussion then builds up as to the next move. Kirkby (1992) says 'the value of discussion cannot be overstated. It is most effective within small groups of two or three' (pages 6-7).

Children playing a mathematical game against each other co-operate playing the game and if they play in teams they quickly learn that to play effectively they must co-operate. Thus playing games provides an opportunity for children to work co-operatively, a recommendation from the DES report (1985) Mathematics from 5 to 16.

Games put pressure on players to work mentally. As Hatch (1998b) observes 'one does not record anything while playing a game unless one has to. Players seem readily to accept that when playing a game a calculator is not normally used; indeed, it often slows the game unacceptably' (page 6). With the concern in the UK about the mental skills of pupils and the pressure to improve them increasing she claims that 'games involving numbers are a rich sort of the kind of practice which is needed' (page 6).

Within the normal classroom situation there are few opportunities and little incentive for pupils to check and justify their work. However within games since cheating is something most children are conscious of there is a strong incentive for players to check each other's mathematics, challenging moves which they think are unjustified.

Some mathematical games provide the opportunity for pupils to make predictions. This could be predicting the consequences of a particular move, deciding whether to go or not; it may be better to miss a turn than to make a move which will ultimately make your position worse. In Percentage Rummy (described on page 10) there may be several possible moves available, and several predictions may be necessary to decide which is the best.

## 3. Pupil experience

Probably the most powerful reason for introducing games into the mathematics classroom is the enthusiasm, excitement and total involvement and enjoyment that many children experience when playing games. As Ernest (1986) notes, ' pupils become strongly motivated, they immerse themselves in the activity, and over a period of time should enhance their attitude towards the subject' (page 2). Games are played in a context in which there is usually help available, Hatch (1998b) found that groups are usually supportive of each other, solving problems for people who are stuck and offering effective peer tuition. Kirkby (1992) too notes the need for pupils to experience success, satisfaction, self-confidence, enjoyment, excitement, enthusiasm, interest and active involvement. He believes that there is 'no medium more powerful for providing these experiences than the use of games' (page 5).

### Disadvantages of using games

Of course there can be disadvantages to using games in the classroom. An understandable worry about including games in mathematics is that this may introduce an added element of competition in the classroom. Ainley (1988) recognises that teachers who work hard to achieve a co-operative atmosphere in their classrooms may feel that the introduction of games would be counter-productive. She points out that games are often offered as a reward for those who have finished their 'work', the hidden messages are clearly that real mathematics cannot be fun and that games are not difficult 'work'. Hatch (1998b) also recognises a heightened noise level, not as much written evidence as managers or parents might like and the need for a lot of organisation of materials as possible disadvantages of using games in the mathematics classroom.

## CLASSROOM INVESTIGATION

I decided to use two games in the classroom to try to improve mental arithmetic skills. I felt this would be most productive if it focused on a particular topic, so my first task was to determine a suitable topic.

All the pupils in the class will be entered for the levels 3-5 examinations in the SATS and therefore will attempt the lower tier mental arithmetic test. As a starting point I gave them a previous test at this level (the sample 1997 paper, shown in Appendix 1). After I had marked them I recorded their results in a grid (shown in Appendix 2). For each pupil I noted whether they had got the question, right, wrong or not attempted it. I then looked at the questions that had the highest number of incorrect or missing answers. As expected there were a range of topics which the pupils had problems with. However what seemed to be the most common thread was the

relationship between fractions, decimals and percentages and doing simple calculations with them, so this is the area I have concentrated on.

To measure the effectiveness of the experiment I wrote a short diagnostic mental arithmetic test covering only the target topics. I used this before I tried the games and then again after we had played the games to see if there was a marked improvement in performance. The test appears in appendix 3 and the initial answers are analysed in appendix 4 using the same grid format as before with the final test results appearing in appendix 5. Only results for pupils who were present for both the initial and final diagnostic tests are recorded.

After the initial test the questions causing most problems seem to fall into two groups:

1.  Conversions from decimals into fractions ( and the reverse).
    Changing 0.3 and 0.5 into fractions were the questions that were most badly done (Q2 and Q15), interestingly changing 0.25 into a fraction proved less of a problem but still more than half the pupils did not get the correct answer. The reverse process converting from fractions into decimals (Q9) was also a big problem. I am hoping that Game 2, in particular, will be able to improve this situation.
2.  Working out fractions of amounts.
    This was covered by Q5 & 10, 75% of the class got both of these questions wrong and one other person got Q5 wrong. I am hoping that Game 1 will have some effect on this.
    Overall, the mean mark for the class before the use of the games was 56%.

**Game 1 - Find the missing number**

This game is based on the game of the same name in Hatch (1998a) page 33. I have however modified the contents of the cards to tie in with fractions, percentages and decimals.

Using the set of cards below, three cards are dealt to each player who places them on the table in front of them, the remaining cards are placed in a stock pile. The dice is thrown by each player in turn ( moving clockwise) and if the number on the dice is the correct missing number for any of the players three cards then they win that card and replace it from the stock pile. The player throwing the dice that turn is first to replace his card, then move clockwise. The winner is the player who has won the most cards when the first of the players runs out of cards.

| | | |
|---|---|---|
| 20% of 30 = ? | $\frac{1}{4}$ of 24 = ? | $\frac{1}{3}$ of 15 = ? |
| $\frac{1}{?}$ of 8 = 4 | 25% of 4 = ? | $\frac{1}{?}$ of 25 = 5 |
| $\frac{1}{10}$ of 10 = ? | $\frac{1}{?}$ of 9 = 3 | 5% of 80 = ? |
| 25% of 24 = ? | $\frac{?}{5}$ of 20 = 8 | $\frac{?}{10}$ of 56 = 5.6 |
| $\frac{1}{?}$ of 100 = 25 | 5% of 40 = ? | $\frac{1}{?}$ of 80 = 40 |
| $\frac{?}{10}$ of 80 = 24 | $\frac{1}{?}$ of 70 = 14 | 10% of 30 = ? |
| 50% of 6 = ? | $\frac{?}{5}$ of 50 = 10 | $\frac{3}{?}$ of 20 = 15 |
| ? % of 200 = 10 | 20% of 20 = ? | 15% of 40 = ? |

I tried playing this game with the class on two separate occasions. The first time I set aside a whole lesson the second time a period of twenty minutes at the end of a lesson.

The class has quite a few awkward characters in it and some time ago I drew up a seating plan which moved pupils away from their friends. For this game they were arranged in groups of 3 or 4, more or less where they would normally sit, away from their own friends. The first few minutes of the lesson were very difficult, the rules of the game were actually quite involved and many of the class had difficulty working out what they actually had to do to play the game, let alone how to cope with the mathematical content of it. I ended up moving around the five groups going through the motions of playing the game with each of them. The cards themselves seemed to fall into three categories, ones that they could easily cope with such as:

$\frac{1}{4}$ of 24 = ? 50% of 6 = ? 10% of 30 = ?

ones that someone in the group could deal with and was prepared to help with, such as:

$$15\% \text{ of } 40 = ? \qquad \frac{1}{?} \text{ of } 9 = 3 \qquad \frac{1}{?} \text{ of } 80 = 40$$

and finally some cards which no one had much idea what to do with and they resorted to asking me. Cards like these, all of which required a reverse process which was either not straightforward or involved unfamiliar numbers:

$$\frac{1}{?} \text{ of } 70 = 14 \qquad \frac{?}{10} \text{ of } 80 = 24 \qquad \frac{3}{?} \text{ of } 20 = 15$$

This proved to be very time consuming for me and left me with little time to actually watch the class playing the game properly.

Most pupils worked out the value of their three cards and because for many of them this proved to be quite a difficult exercise at the beginning they wrote (unprompted by me) the missing numbers in the back of their books. This practice seemed to reduce as the game progressed. The other technique I noticed with a few students was for them to arrange their cards in order based on the numerical value of the missing numbers, they found this to be helpful when they played the game. I myself had used this when I had tried the game out.

By the time most groups were on to playing the second or third game they had mastered the logistics of playing the game and many of them felt more confident with the mathematical content of it. After about thirty five minutes some of the naughty boys and girls in the groups were developing ways of cheating and at this point we left the game and moved onto other work. A few days later I played the game for a period of about twenty minutes at the end of a lesson. The more motivated members of the class were keen to play and had remembered the basic rules of the game, many of them had however forgotten how to cope with some of the cards particularly the third category mentioned above, although the game generated a good deal of discussion certainly in some of the groups. Once again there were problems with some of the pupils in the class and
reluctantly I had to remove them from the game situation. For some of these pupils the competitive instinct was too strong and winning no matter how had proved to be too strong a motive.

After the two sessions on the game I was reluctant to play it again, there was not much enthusiasm to play it again and many had found the content had been too difficult to cope with in a game.

**Game 2 - Percent Rummy**
This is taken from Kirkby (1992) page 38, and is based on the well known card game. The pack consists of the cards below and is made up of 12 groups, each with 4 cards of equivalent value:

| | | | |
|---|---|---|---|
| 0.25 | 25% | $\frac{1}{4}$ | $\frac{25}{100}$ |
| 0.6 | 60% | $\frac{3}{5}$ | $\frac{6}{10}$ |
| 0.7 | 70% | $\frac{7}{10}$ | $\frac{70}{100}$ |

If there are two players then each is dealt ten cards, if there are three of four players then each receives seven cards. The remainder of the pack is placed face down in a stock pile.

The top card is turned up and discarded face up next to the stock pile. The player to the left of the dealer takes the top card from either the stock pile or the discard pile. He/she then attempts to lay down groups of three or more cards of the same value. Finally he/she must discard one card onto the discard pile. Once a player has put down a group, he/she may also add a card to groups formed by other players. The first player to discard all his/her cards is the winner.

From the beginning this game proved to be much more successful. Once again the logistics of playing the game needed careful explanation, several of the class were not familiar with the game and those that were tried to extend percent rummy to include runs which are allowed in the normal rummy game. This time I let the class sit in friendship groups and this too proved to be more successful, many of them felt like they were playing 'proper' card games to the extent that chewing of gum seemed to be widespread during the game.

For the purposes of this experiment the class played the game on two occasions. As with the first game I allowed most of a fifty minute lesson the first time for them to come to grips with it, and then a second session of twenty minutes. The first time we played the game there was a great deal of discussion with pupils asking each other whether cards were equivalent, the group of cards involving one eighth caused the most problems but by the end of the two sessions most of the class seemed to have remembered this group. The cards involving tenths they were very happy with and many of the pupils seemed pleased with themselves that they had grasped the connections. The only cards that still seemed to be a problem to many of the pupils at the end of the second session were the groups involving:

| $\frac{1}{5}$ | $\frac{2}{5}$ | $\frac{3}{5}$ | $\frac{4}{5}$ |
|---|---|---|---|

Linking these fractions with the remainder of their group requires a more sophisticated understanding of equivalence than most of the other groups which only require the link between tenths and hundredths.

Results of diagnostic test

Analysis of the diagnostic test after the use of the games reveals some interesting findings. The average mark for the class went up from 56% to 68% and no pupil got a worse mark on the final test than the first one. One of the most enthusiastic participants in the games nearly doubled her score from 8 to 15 marks out of 20. The improvements are clearly related to improvements on particular questions. Changing from decimals to fractions improved significantly as table 1 shows:

Question
number Decimal to change to a fraction Incorrect answers on first test Incorrect answers on final test

| Question number | Decimal to change to a fraction | Incorrect answers on first test | Incorrect answers on final test |
|---|---|---|---|
| 2 | 0.3 | 15 | 3 |
| 7 | 0.25 | 10 | 2 |
| 15 | 0.5 | 15 | 9 |

Table 1

As well as the improvements in the answers to these questions there were clear shifts to thinking in terms of tens and hundreds. Table 2 shows the change in response to

question 7 changing 0.25 to a fraction.

| Question 7 | Number of pupils giving the answer | |
|---|---|---|
| | $\frac{1}{4}$ | $\frac{25}{100}$ |
| Initial test | 10 | 0 |
| Final test | 4 | 10 |

Table 2

Surprisingly however 0.5 caused the class much more problems than any of the other conversions, even though there has been a big improvement still more than half of them are getting this wrong, table 3 on the next page shows the pattern of errors.

| Question 15 | Numbers of pupils giving the answer | | | | |
|---|---|---|---|---|---|
| | $\frac{1}{2}$ | $\frac{5}{10}$ | $\frac{50}{100}$ | $\frac{5}{100}$ | $\frac{1}{5}$ |
| Initial test | 1 | 1 | 0 | 0 | 4 |
| Final test | 3 | 3 | 1 | 2 | 2 |

Table 3

Other conversions from fractions to decimals and percentages also showed big improvements with fractions in the tens system being easier to cope with as can be seen from this table.

| Question number | Fraction to change to decimal or % | Incorrect answers on first test | Incorrect answers on final test |
|---|---|---|---|
| 9 | $\frac{3}{4}$ | 11 | 6 |
| 12 | $\frac{1}{2}$ | 2 | 0 |
| 19 | $\frac{3}{10}$ | 6 | 1 |

Table 4

All these questions were addressed in the percent rummy game. The other questions showed very small improvements (mostly an extra 1 or 2 pupils getting them right).

**CONCLUSION**
The playing of these two games has given pupils the opportunity to practice and reinforce the skills associated with some mental calculations involving fractions, decimals and percentages. Pupils were very actively involved with the Percent Rummy game, but many had great difficulties with Find the Missing Number and I feel that after a while they 'switched off' .The diagnostic test that was administered before and after the test shows big improvements on the skills practised in Percent Rummy, namely the connections between common fractions and their decimal and percentage equivalents. There is no noticeable improvement on skills practised in Find the Missing Number game. This is in common with the research by Bright and Wheeler (1982) who also had varying success with their games.

The games provided pupils with different ways of working. Both involved pupils working in groups and it was noticeable with this particular class how important the make-up of the group was. Friendship groups seemed to be more successful, I suspect because it tended to keep the more distruptive pupils together rather than spreading them throughout all the groups. Pupils within friendship groups also tended to work co-operatively discussing the game and the validity of various answers.

Although I had not mentioned the use of calculators to the class they clearly felt they were not appropriate and one or two pupils were told by the rest of their groups to put them away, putting pressure on them to work mentally. In the first game Find the missing number pupils certainly found a high proportion of the calculations difficult to perform and many pupils noted answers down to avoid repeating calculations unnecessarily. Within both games pupils checked each other's work and when there was any doubt a pupil was called upon to justify their answer, very occasionally I was called into provide the final word but certainly in Percent Rummy each group resolved their own disagreements. Within Percent Rummy there are many choices to be made about what to do next, most of these are not obvious to the observer but cries of "I don't know which to throw away" were quite common towards the end of the game and obviously pupils need to make predictions and work through the consequences of each option in their own mind.

As well as the advantages of playing the games there were disadvantages. Both the games I had chosen involved packs of cards, these were fairly time consuming to make especially as each group had different coloured cards. The different colours did help to keep each set of cards separate but there was always the need to make sure each pack was complete at the end of a session: it is amazing how many cards get dropped on the floor and how many pupils can't accurately count up to forty-eight! I was reluctant to leave the Find the missing number game when pupils were still not mastering it but I was very conscious of the need for pupils to the enjoy games and when a significant element of the class were struggling and clearly enjoyment wasn't the major reaction, I felt it was better to leave it. A great deal of effort had gone into producing a resource that had not been used very much, however there is always the chance to use them with a more able group.

The noise level was significantly higher during these games sessions, this was not just increased discussions between pupils but also the fact that excitable pupils also tend to shout rather than talk. I was particularly surprised at the increased incidence of gum chewing during games and this was also evident with a top set that I used Percent Rummy with, it was clear from the conversations I had with them that they felt like they were playing cards with friends and chewing gum was part of that experience. With this year nine class I did feel that these games session were very hard work, there are several pupils with behavioural difficulties and they responded differently to the games situation. The most awkward boy in the class loved playing the games and was no trouble at all, however there were a couple of other boys who were determined to win whatever method was used and they together with a girl who was very good at disrupting the games did cause problems. Generally they were containable for a while and then had to be moved out of the games situation and on to other work.

Overall I was pleased with my efforts on Percent Rummy, the children enjoyed the game and their mental arithmetic scores improved as a result of it, as an added bonus I have used this game with other classes. I never felt comfortable using Find the missing number with this class, it may however be successful with more able chuldren. Many of the class really enjoyed their time playing these games. As we had usually done this on a Friday they now have an expectation of playing games for part of the lesson on Friday and we have tried many other games that I had discovered in my research for this experiment. Clearly children can and do enjoy games in the mathematics classroom but initally it does require a great deal of preparation and testing to see which are appropriate. Having done that preparation they are a valuable resource that can be used repeatedly, sometimes with many classes.

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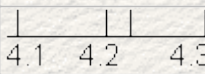
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**Appendix 1 : Sample SATS mental arithmetic test from 1997**

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### Lower tier sample test questions

| | Pupil sheet |
|---|---|
| *For the first group of questions, you will have 5 seconds to work out each answer and write it down* | |
| 1. Add together eight, two and seventeen. | |
| 2. Write the number that is six less than one hundred. | |
| 3. What is six hundred and eighty-seven to the nearest hundred? | |
| 4. What is seven multiplied by eight? | |
| 5. Write the number twenty thousand and four in figures. | |
| 6. Write nought point five as a fraction. | |
| 7. Change nine and a half metres into centimetres. | cm |
| 8. What is three point two multiplied by one hundred. | |
| *For the next group of questions, you will have 10 seconds to work out each answer and write it down* | |
| 9. How many halves are there in three whole ones? | |
| 10. Fifty-eight percent of the children in a school are girls. What percentage are boys? | % |
| 11. The side of a square is three metres. What is the area of the square? | $m^2$ |
| 12. A train journey starts at seven forty. It lasts for forty-five minutes. At what time does it finish? | 7.40    45 |
| 13. In the morning the temperature is minus two degrees Celsius. What will be the temperature after it rises nine degrees? | $^{o}C$ |
| 14. On your sheet is a scale . Estimate the number shown by the arrow. | 4.1   4.2    4.3 |
| 15. Write a factor of thirty-five, which is greater than one. | |
| 16. What is eight thousand divided by ten? | |
| 17. What number is six squared? | |
| 18. How many nineteens are there in three hundred and eighty? | 380 |
| 19. Colin has six pounds fifty pence. He wants to buy a computer game which costs nineteen pounds twenty-five pence. How much more money does he need ? | |
| 20. Twenty five per cent of a number is thirty. What is the number? | |
| 21. Look at the angle on your sheet. Estimate the size of the angle in degrees. | |

**Appendix 1 : Sample SATS mental arithmetic test from 1997**

*For the next group of questions, you will have 15 seconds to work out each answer and write it down*

| | Pupil sheet |
|---|---|
| 22. For this question there are some numbers on your sheet. Draw a ring around each of the even numbers. | 18  25  26<br>32  39 |
| 23. A book costs two pounds and eighty pence.<br>Ben saves fifty pence at the end of each week.<br>How many weeks will it be before he can buy it? | |
| 24. The numbers on your sheet show the number of visitors to a museum on three days.<br>What is the total number of visitors? | 215  387  400 |
| 25. What is the cost of four video tapes at two pounds ninety-nine pence each? | |
| 26. Subtract the sum of thirteen and fourteen from thirty-five. | |
| 27. On your sheet are two numbers. Write the number which is half-way between them. | 7.5     13.5 |
| 28. One eighth of a number is two point five.<br>What is the number? | |

Appendix 2: Analysis of answers to sample SATS mental arithmetic test from 1997

| | gw | bb | lh | smc | sm | an | pf | aw | je | mb | mc | sb | gr | dsw | m | rd | ck | hk | inc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | x | | | | | | | | x | | | | | | | | | 2 |
| 2 | | x | ? | | | | | | x | | | | | | | | | | 3 |
| 3 | | ? | | | | | | | x | | | | x | | | | | | 3 |
| 4 | x | ? | ? | ? | | | x | | ? | x | | | ? | | | | x | | 9 |
| 5 | x | x | | ? | x | x | | | x | x | | | | x | | | | x | 9 |
| 6 | x | ? | ? | | | x | x | ? | x | x | x | ? | | x | | | x | x | 13 |
| 7 | | x | x | x | | x | | ? | | | x | | ? | | | | | x | 8 |
| 8 | x | x | x | x | | x | | ? | x | x | ? | | x | x | | x | x | x | 14 |
| 9 | | | | | | | | | | | | | | | | | | | 0 |
| 10 | | x | | | | | | | x | | | | | | | | | | 2 |
| 11 | x | | | x | | | x | x | | ? | | | x | x | x | | | | 8 |
| 12 | x | | | | ? | | | | | | | | | | | | | | 2 |
| 13 | | | | | ? | x | | | x | | | | | | | | | | 3 |
| 14 | | | x | | | | | | | x | | | | | | | | | 2 |
| 15 | x | | ? | ? | x | | | ? | | ? | | | | | | | x | | 8 |
| 16 | | | x | | x | | | | | | | | | | | | | | 2 |
| 17 | | | ? | | x | x | ? | x | ? | ? | | | | | | | | | 7 |
| 18 | x | ? | ? | x | | x | ? | x | x | ? | | | | x | | | | x | 11 |
| 19 | x | x | x | x | | | ? | | x | | | ? | ? | x | x | x | x | x | 12 |
| 20 | x | ? | ? | ? | x | ? | x | ? | x | | ? | | | | | | x | x | 12 |
| 21 | x | x | x | | | x | x | x | x | x | | x | x | | x | x | x | x | 14 |
| 22 | | | | | | | | | | | | | | | | | | x | 1 |
| 23 | | | | | | ? | | | | | | | | | | | | | 1 |

| | | | | | | | | | | | | | | | | | | inc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | x | x | | | | x | | x | | | | x | ? | | | | x | 7 |
| 25 | x | ? | ? | x | x | ? | | ? | | x | x | ? | ? | x | | | | 12 |
| 26 | | | | ? | | ? | x | | x | | | | | ? | | | | 5 |
| 27 | | x | | x | | x | x | ? | x | x | | | x | x | | | x | 10 |
| 28 | x | ? | ? | ? | x | ? | x | | ? | ? | ? | | ? | | | ? | x | 13 |
| Tot | 14 | 10 | 16 | 12 | 23 | 12 | 17 | 17 | 12 | 14 | 18 | 26 | 19 | 18 | 24 | 24 | 19 | 16 | |

Each numbered line corresponds to that question number. Each column represents a different pupil. Blank squares denote a correct answer, an x denotes an incorrect answer and a ? shows the question was not attempted. The final column (inc) shows how many pupils did not correctly answer that question.

Appendix 3: Diagnostic mental arithmetic test

1. What is 10% of 50?
2. Write 0.3 as a fraction.
3. What is 57 x 10 ?
4. Half of a number is 6, what is the number?
5. What is 1/3 of 75?
6. What is 20% of 70?
7. Write 0.25 as a fraction.
8. What is 62 x 100 ?
9. Write 3/4 as a decimal.
10. What is 1/8 of 56?
11. One quarter of a number is 30, what is the number?
12. What is 1/2 as a percentage?
13. What is 4.3 x 10 ?
14. What is 15% of 80?
15. Write 0.5 as a fraction.
16. 1/8 of a number is 5, what is the number?
17. What is 3.4 x 100 ?
18. 25% of a number is 10, what is the number?
19. Write down 3/10 as a percentage.
20. What is 2.7 x 1000 ?

Appendix 4: Analysis of diagnostic mental arithmetic test before playing the games.

| Pupil | gw | bb | lh | smc | sm | an | pf | aw | je | mb | sb | gr | cs | rd | ck | hk | incorrect |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Q |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | incorrect |
| 1 |  |  |  |  |  |  |  |  |  | x |  |  |  |  |  |  | 1 |
| 2 | x | x | x | x | x | x | ? | x | ? | x |  | ? | x | x | ? | x | 15 |
| 3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| 4 |  |  |  |  |  |  |  |  |  | x |  |  |  |  |  |  | 1 |
| 5 | ? | ? | ? | x | ? | x | ? | ? | ? |  | ? | ? | x | ? | ? |  | 13 |
| 6 |  | x | ? | ? |  |  |  |  |  | ? |  |  |  | x |  |  | 5 |
| 7 | x | ? | ? | ? |  | ? |  | ? |  | x | x | x |  | x |  |  | 10 |
| 8 |  |  |  | ? |  |  |  |  |  |  |  | ? |  |  |  |  | 2 |
| 9 | x | x | ? | ? |  | x |  | ? | x | x | x |  | x | x |  |  | 11 |
| 10 |  | ? | ? | ? | ? | x | ? | ? | ? |  |  | ? | ? |  | ? | ? | 12 |

| Q | | | | | | | | | | | | | | | | | incorrect |
|----|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|-----------|
| 11 | | x | x | | | | | | ? | | | | | x | x | | 5 |
| 12 | | | | x | | x | | | | | | | | | | | 2 |
| 13 | | x | | x | | | | | x | x | | | | x | | | 5 |
| 14 | x | x | x | x | | x | | ? | x | ? | x | | | x | | | 10 |
| 15 | x | ? | ? | ? | x | x | x | ? | ? | x | x | ? | x | | x | ? | 15 |
| 16 | x | ? | ? | x | | | | ? | ? | ? | | | x | | ? | x | 10 |
| 17 | | x | x | | | | | | ? | x | | | | x | | | 5 |
| 18 | ? | ? | ? | | | ? | ? | | ? | | | | x | | ? | x | 9 |
| 19 | | | ? | x | | | ? | | ? | ? | | x | | | | | 6 |
| 20 | | | | | | | | | ? | x | x | | | x | x | | 5 |
| Tota 1 | 12 | 8 | 7 | 6 | 15 | 10 | 15 | 11 | 9 | 8 | 15 | 13 | 12 | 17 | 8 | 12 | Average 11.13 |

Each numbered line corresponds to that question number. Each column represents a different pupil. Blank squares denote a correct answer, an x denotes an incorrect answer and a ? shows the question was not attempted. The final column (incorrect) shows how many pupils did not correctly answer that question.

Appendix 5: Analysis of diagnostic mental arithmetic test after playing the games.

| Pupil 1 | gw | bb | lh | smc | sm | an | pf | aw | je | mb | sb | gr | cs | rd | ck | hk | |
|---------|----|----|----|-----|----|----|----|----|----|----|----|----|----|----|----|----|---|
| Q | | | | | | | | | | | | | | | | | incorrect |
| 1 | | | | | | | | | | | | x | | | | | 1 |
| 2 | | | | | | | ? | ? | | | | | | x | | | 3 |
| 3 | | | | | | | | | | | | | | | | | 0 |
| 4 | | | | | | | | | | | | | | | | | 0 |
| 5 | x | ? | ? | x | | ? | | ? | | | | | ? | | x | | 8 |
| 6 | | ? | ? | x | | ? | | | | | x | | | x | | | 6 |
| 7 | | | ? | | | | ? | | | | | | | | | | 2 |
| 8 | | | | | | x | | x | | | | | | | | | 2 |
| 9 | | x | ? | x | | x | | | ? | ? | | | | | | | 6 |
| 10 | ? | ? | ? | x | | ? | ? | ? | ? | | | ? | ? | x | x | ? | 13 |
| 11 | | x | ? | | | | | | | ? | | | | | ? | ? | 5 |
| 12 | | | | | | | | | | | | | | | | | 0 |
| 13 | | x | | x | x | | | | | | | | | | x | | 4 |
| 14 | | ? | x | x | x | x | | | | | x | x | | | x | | 8 |
| 15 | x | | ? | x | | ? | ? | ? | | | | x | x | | x | | 9 |
| 16 | x | ? | ? | ? | | x | | ? | | | x | | x | | ? | ? | 10 |
| 17 | | x | | x | x | x | | | x | x | | | | | x | | 7 |
| 18 | x | ? | ? | | | ? | | | | ? | | x | | | x | x | 8 |
| 19 | | | ? | | | | | | | | | | | | | | 1 |
| 20 | | x | | x | x | x | | | x | x | ? | | | | x | | 8 |
| Tota 1 | 15 | 9 | 9 | 10 | 16 | 10 | 17 | 15 | 13 | 15 | 17 | 15 | 15 | 19 | 9 | 15 | Average 13.69 |

Each numbered line corresponds to that question number. Each column represents a different pupil. Blank squares denote a correct answer, an x denotes an incorrect answer and a ? shows the question was not attempted. The final column (incorrect) shows how many pupils did not correctly answer that question.