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Interactive multimedia and concrete three-dimensional modelling

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Abstract A multimedia package for teaching about the phases of the moon to Year 8 (12-year-old) students was compared with a conventional three-dimensional modelling approach. Both methods were highly and equally effective in terms of student learning, and the effectiveness of the multimedia package did not depend on a student's experience of computers or attitude towards computers. The package was also equally effective for male and female students.

Keywords: Attitudes; Interactive multimedia: Learning astronomy; Modelling; School students

Introduction

Interactive multimedia packages not only permit the presentation of learning materials via text, graphics, audio, animation, and video but, through the control capabilities of computers, have the potential for involving students actively in their learning (Hornung, 1992; Latchem *et al*, 1993; Pina & Saveye, 1992). Multimedia packages therefore have particular potential in those areas of the curriculum where the range of student learning activities is otherwise severely limited. Moreover they also have a potential role in supporting teaching in areas where teachers have limited experience. The teaching of astronomy in primary and secondary schools, as currently required by the National Curriculum in England and Wales, is an area of science education where both of these problems — the limited scope for student activities and limited teacher expertise — are likely to occur in many schools. There are no opportunities for student experiments in astronomy and fewer opportunities for practical investigations than in many other areas of science (Preece & Clish, 1985; Baxter, 1991). Astronomy is also an area of science where students and teachers have many misconceptions (Baxter, 1995; Mant & Summers, 1993; Preece, 1985; Sadler, 1987).

For the purposes of the present investigation, a multimedia package was developed for teaching a topic in astronomy — the phases of the Moon — to students aged about 12 years. A general problem with multimedia presentations of astronomical phenomena is the representation of three-dimensional structures

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on a two-dimensional screen (Lanciano, 1994). Clish (1985) has claimed that three-dimensional working models are essential in the teaching of astronomy, and the topic of the phases of the Moon is often taught in secondary schools using a concrete three-dimensional classroom modelling exercise. Accordingly in the present study these two approaches — using a multimedia package and using a modelling exercise — were compared, with student learning as the criterion of effectiveness.

Multimedia system

The interactive multimedia package ‘phases of the moon’ used in this study was produced by the authors using ‘Hyperstudio’ on a Macintosh computer. The package included text, graphics, and animations. Links were made so that the students could browse among the text, graphics and animations, or control the animations, by clicking buttons on the screen with the mouse. The package included questions with links to relevant sections. As pointed out by Cockerton and Shimell (1997), programs of this type can overload the user with navigational problems. In order to overcome this difficulty certain structural constraints were applied to the program. Figure 1 shows the areas covered; the arrows give an indication of the structural constraints.

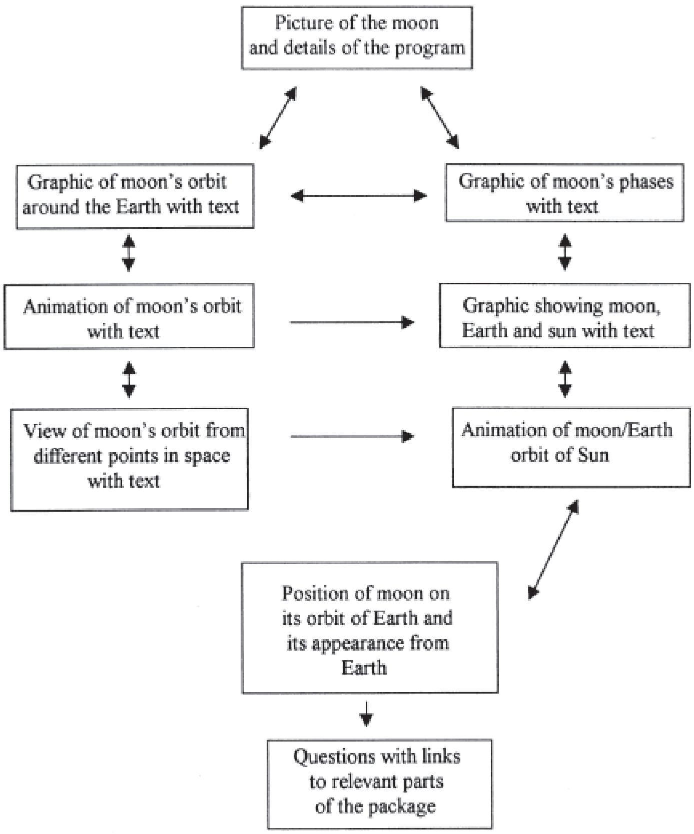

Fig. 1. Structural overview of the multimedia package

The package was designed to cover the following topics about the moon:

(a) *Where it gets its light.* This was achieved by diagram and animation showing that only the side of the moon facing the Sun is illuminated.

(b) *How it orbits planet Earth.* The conventional two-dimensional orbit diagram was displayed showing the moon's orbit as a flattened ellipse. In order to confront any misconception about its orbit, the students could choose an animation that viewed the orbit as seen when looking towards one of the poles.

(c) *The cause of its phases.* The cause of the moon's phases was shown in the conventional two-dimensional way using computer graphics. This was then reinforced by (d) below.

(d) *Relating its appearance from Earth with its position on its 28-day orbit.* The students were able to select a position on the moon's orbit of planet Earth by clicking the mouse on that position. They were then shown how the moon would appear when viewed from the Earth (see Fig. 2).

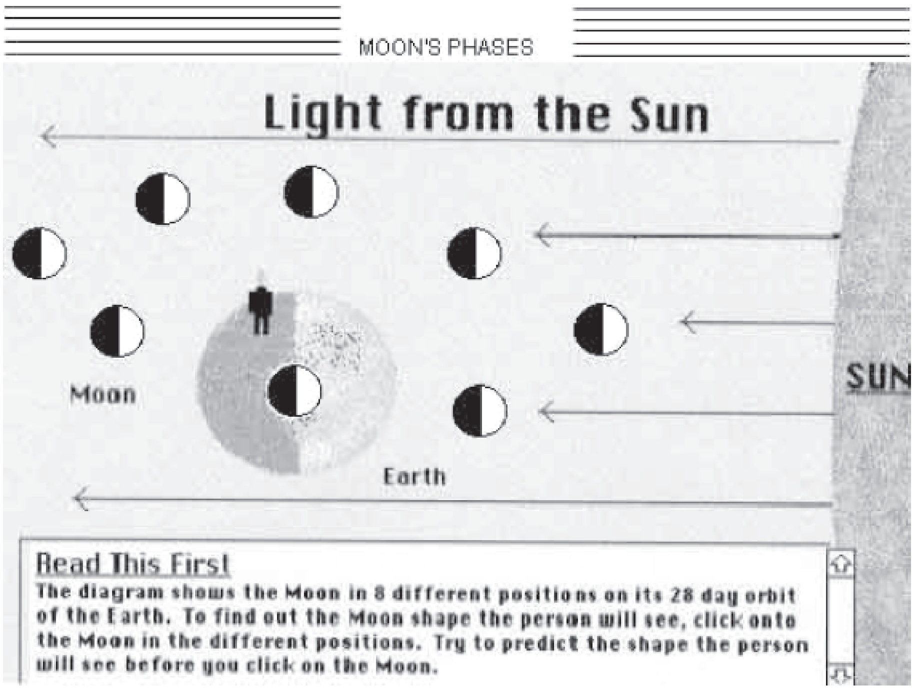

Fig. 2. How the moon would appear when viewed from the Earth.

An explanation screen with text and diagrams was available.

Finally, a series of questions on the topics (a) to (d) with appropriate links allowed students to check their knowledge and be returned to the learning sections if necessary.

Three-dimensional modelling exercise

This lesson used the light from an OHP to represent the sun and a beach ball to model the moon. The beach ball was painted in two halves — one half yellow to represent reflected sunlight and one half black to represent the side facing away from the sun.

Students were asked to move towards the centre of the classroom. The models were explained by the teacher who, standing towards the edge of the classroom, then held the beach ball so that the yellow side was facing the OHP sun model. The black side was facing the students. The teacher then made one full circle of the group of students making sure that the yellow side of the beach ball was always facing the OHP. The students were asked to say how much of the lit half they could see as the teacher did one orbit of the group.

Subjects

Three Year 8 science classes in two comprehensive schools took part in this study. Two of the classes were of mixed ability and one class was categor-ised as low ability by the school. The total sample consisted of 63 students.

Instruments

Astronomy pretest

The *astronomy pretest* consisted of seven multiple-choice items about the sun and the moon. The test focussed on assessing knowledge of the phases of the moon. Examples of the items are given in Fig. 3.

Posttest

The *posttest* consisted of ten questions, mainly concerned with the phases of the moon. Six of the questions were identical to items in the *astronomy pretest*. The final question on the *posttest* concerned the phases of Venus and was designed to test the ability of students to generalise the knowledge acquired about the moon to another astronomical body. Examples of questions are given in Fig. 3.

Computer use questionnaire

This consisted of ten statements concerning computer use (e.g. 'I use a computer every day', 'I have a computer at home') to each of which students were asked to respond with a tick to show agreement, a cross to show disagreement or a question mark to show uncertainty. A response indicating computer use was scored 2, an uncertain response was scored 1, and a response indicating little or no use of computers was scored 0.

Attitudes to computers questionnaire

This consisted of eight statements indicating positive or negative attitudes towards computers (e.g. 'I feel very confident when I use computers', 'computers are boring'), to each of which students were asked to respond on a five-point scale ('strongly agree', 'agree', 'neutral', 'disagree', 'strongly disagree'). Responses were scored 0, 1, 2, 3 or 4, with a high score indicating a strongly positive attitude. This instrument was originally developed by Kirkman (1997) as the confidence subscale of an *attitudes towards computers* questionnaire. Factor analysis and question analysis, with a sample of Year 8 students, were used to refine and evaluate the instrument and Kirkman reported very substantial item-total correlations (> 0.50) and an overall reliability (Cronbach's alpha) of 0.86 for the subscale.

(4) The Moon shines because:

(i) It reflects light from the planets.
(ii) It reflects light from the stars.
(iii) It reflects light from the Sun.
(iv) It produces its own light.

(5)

Tick the shape you think the person will see the Moon make.

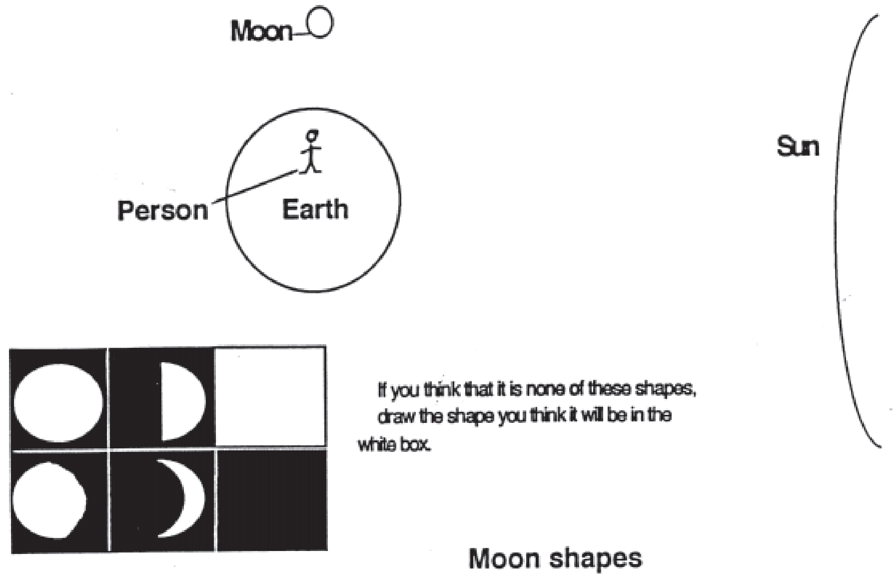

Fig. 3. Examples of items common to astronomy pretest and posttest.

Procedure

One week before the experimental intervention, all students took the *astronomy pretest*, the *computer use* questionnaire and the *attitudes to computers* questionnaire.

For each class the experimental lesson began with a whole class activity lasting for fifteen minutes. The aim of this session was to introduce the topic and to give the students a common starting point.

The students were first asked to write down three things that they knew about the moon. This activity was done individually. Students were then asked to share their ideas with a partner. Each pair then shared their ideas with another pair. Each group of four was asked to identify one point of agreement and one point of disagreement. A spokesperson for each group then told the rest of the class about the point of agreement and the point of disagreement. Throughout this activity the teacher's role was that of a neutral chairperson. At the end of this activity a two-minute clip from the video 'The Eagle Has Landed' was shown. The section selected showed man's first steps on the moon.

Each class was then divided at random into two approximately equal groups for the remaining thirty minutes of the lesson. Group 1 studied the phases of the moon through the interactive multimedia package, students working in pairs at a computer. Group 2 studied the phases of the moon through the three-dimensional modelling demonstration. In each class the introductory activity was led by the same person, a secondary school teacher who was also a researcher attached to Exeter University. This teacher also supervised work with the multimedia package. The regular science teacher for each class taught the phases of the moon with the three-dimensional modelling demonstration, using a lesson plan provided by the researchers.

One week after the experimental intervention, all students took the *astronomy posttest*.

Results

Reliability of scores

A question analysis was carried out on the *posttest* scores, yielding question-total correlations (corrected for inclusion of the question in the total), which acted as discrimination coefficients, and an overall reliability coefficient (Cronbach's alpha). One question had a negative discrimination coefficient and was eliminated from further analyses. The alpha coefficient for the scores on the resulting nine-question test was 0.65. The *astronomy pretest* was found to have only very low internal consistency reliability and so total scores were not calculated on this instrument.

As a result of a question analysis conducted for the *computer use* questionnaire, one item was removed and the scores on the resulting nine-item instrument had an alpha reliability of 0.85. Cronbach's alpha for scores on the *attitudes to computers* questionnaire was 0.86, identical to the value reported by Kirkman (1997). The correlation between the *computer use* and *attitudes to computers* scores was 0.76 ($p < 0.001$), indicating a substantial positive relationship between these measures.

Pretest differences

There was a significant difference ($p < 0.05$) between the performances of students taught by the two different approaches on only one item in the *astronomy pretest*. This item concerned the period of the Earth's orbit around the sun. On the remaining six *pretest* items, which concerned the phases of the moon, there were no significant differences between the two groups.

A significant point-biserial correlation ($r = -0.27$, $p < 0.05$) between *teaching approach* (computer = 1, three-dimensional modelling = 0) and total *computer use* scores was also found. For this reason, *computer use* was used as a covariate in some analyses.

Gender effects

The point-biserial correlation between *gender* (male = 0, female = 1) and *computer use* was - 0.25 ($p < 0.05$) and the correlation between *gender* and *attitudes to computers* was - 0.33 ($p = 0.01$). (Note that testing the significance of these point-biserial correlation coefficients is equivalent to *t-tests* of the significance of the differences between male and female mean scores). These correlations indicate definite but weak relationships, with females reporting less use of computers and less positive attitudes towards computers than males. However, the correlation between *gender* and *posttest* scores was 0.19 ($p > 0.05$), indicating a higher mean score for females than for males, although the difference was not statistically significant.

Ability effects

Students in the low ability group were given an *ability* score of 0 and all other students were given an *ability* score of 1. Even with this very crude ability classification, the correlation between *posttest* scores and *ability* was 0.71 ($p < 0.001$). However, the correlations between *ability* and *computer use* and between *ability* and *attitude towards computers* were negligible and not significant ($p > 0.05$).

Teaching effects

The point-biserial correlation between *teaching approach* (computer = 1, three-dimensional modelling = 0) and *posttest* score was 0.12 ($p > 0.05$), indicating no significant differences, on average, between students taught by the two methods. This finding was confirmed in an analysis of covariance, with *computer use* as the covariate, showing that there were no significant effects of teaching approach on *posttest* scores after adjusting for the difference between the groups on the *computer use* variable (i.e. with a statistical matching on computer use). The correlation (phi coefficient) between *teaching approach* and the scores on the 'phases of Venus' item was also not significant ($\phi = 0.062$, $p > 0.05$), indicating no differential effect of teaching method on the performance on this item testing knowledge application.

As six questions were common to the *astronomy pretest* and the *posttest*, it was possible to explore the gain scores on this subset of items. Again, no significant differences ($p > 0.05$) were found between the two teaching approach groups on mean gain scores, both with and without adjusting for the *computer use* variable. However, the mean gain for all students on these common items was highly significant ($p < 0.001$), with an effect size (mean gain divided by the standard deviation of the scores on the *pretest* for this subset of items) of 1.12. This is a 'large' effect (Cohen, 1977), showing the effectiveness of both teaching approaches.

There remains the issue of whether the learning which took place in the 'computer' group depended on students' attitudes towards computers or the extent of their prior computer usage. In fact, for students in the computer group, correlations of both *posttest* scores and *gain* scores with scores on either the *attitude to computers* or the *computer use* variables were not significant ($p > 0.05$).

Concluding remarks

The main finding in this study is that the two methods of teaching about the phases of the moon were equally effective. As Watkins *et al.* (1997) have noted, attaining parity with conventional teaching can be a useful achievement. Moreover the student learning, as shown by the gain in achievement scores in the questions common to the pretest and posttest, was greater than one standard deviation of pretest scores. This 'large' value for effect size indicates that using the multimedia package was a very effective way of teaching about the phases of the moon. It is noteworthy that the effectiveness of the package did not depend on a student's experience of computers or attitude towards computers, although scores on the achievement tests were, as expected, strongly related to student ability.

It must be acknowledged, of course, that using a computer-based approach is much more expensive than traditional low-technology teaching (e.g. with a beach ball to represent the Moon). If multimedia packages simply attain parity with a good teacher using traditional methods, considerations of cost will generally favour the latter. However if computer hardware is already in place, to provide, for example, simulations of experiments that cannot be performed in school laboratories, then the marginal costs of using a multimedia package will be low. Moreover a multimedia approach could be a useful backup to conventional teaching, giving students a second opportunity to understand difficult concepts. Alternative ways of engaging and motivating learners are particularly valuable in an area, such as astronomy, in which there is a lack of varied student activities. Familiarising students with interactive multimedia technology and giving them confidence in its use is, of course, valuable in itself, as there are topics in science which students can only explore through computer simulations.

It appears that the use of a multimedia approach is particularly valuable, however, in areas of the science curriculum where teachers are known to have many misconceptions — 'blind lead blind up a blind alley' is Maddox's (1978) chilling phrase. Multimedia packages could provide some teachers with significant support in areas where they lack confidence and in which their knowledge is less than secure.

The multimedia package was equally effective for male and female students, although astronomy is an area of the curriculum where a gender gap in favour of males is commonly found (Preece *et al.*, 1999). This gender effect may be related to a similar gap between males and females in spatial ability (Hacker, 1986), as astronomy is a topic which makes heavy demands on spatial understanding. Further investigation of the role of spatial ability in learning via computer animated material would be worthwhile (Hays, 1996). The present research suggests that interactive multimedia packages with animated graphics may have a particularly useful role to play in supporting learning in areas in which spatial understanding is important.

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