Making Ballistas With Mathematics, Science and Technology

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Previous work done at Trinity High School[1] involved joint teaching and assessment of attainment in Mathematics and Science. The report explored the possibility of joint work in Mathematics and Technology. It envisaged, in particular, the possibility of teaching and assessing practical problem solving skills together, and interpreted some of the National Curriculum Statements of Attainment in Mathematics (ATs 1 and 9) in terms of those in the technology document (ATs 1 to 4).

The present work was conducted with a mixed ability first year (Year 9) class in a secondary school by a teacher of mathematics and technology in Mathematics, Science and Technology lessons. A wide range of statements of attainment were selected from the three subject documents at Levels 3 and 4 which were thought to be appropriate for the students' attainment in the chosen activity. Observations of the work done by students and discussion of the written reports allowed us to select a group of 33 attainment targets relevant to the activity. These are shown in the table at the end of this article. These constitute aims for the activity as an element of a programme of study. We also believe that the activity can provide evidence of students' individual attainment of these aims, though the techniques involved are not the subject of this report.

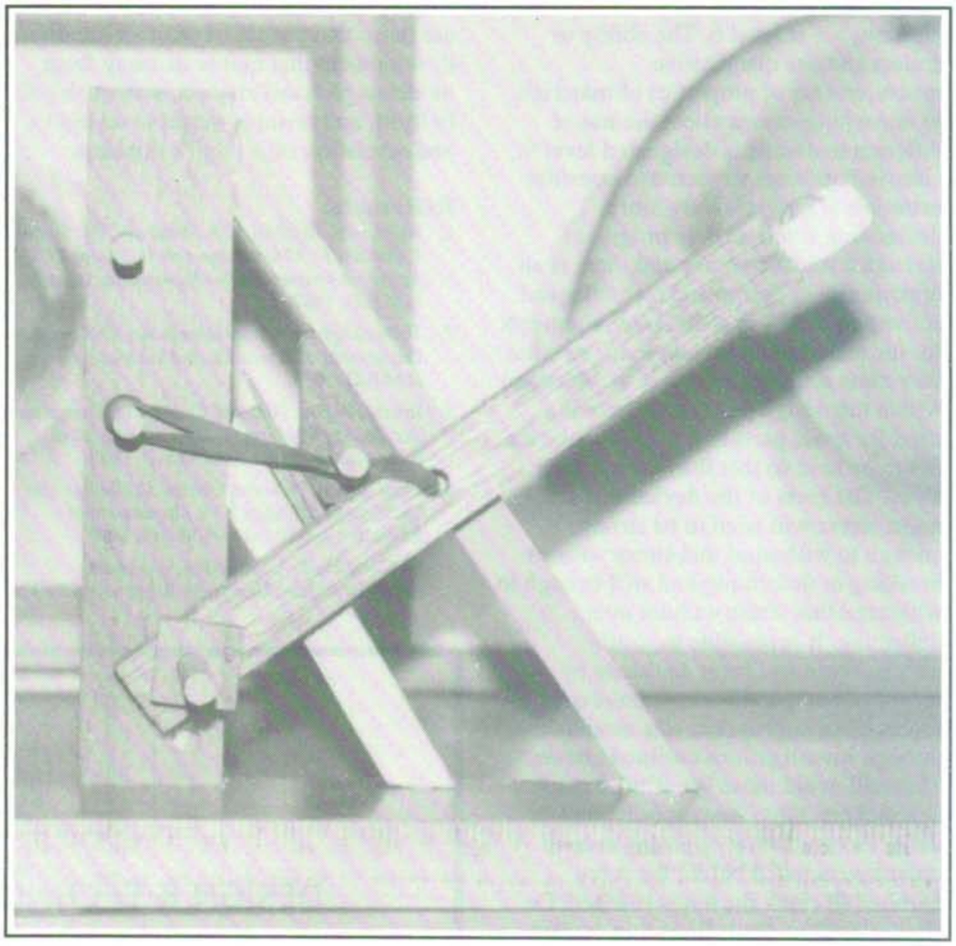
The programme of activity

The class were provided with a simple, prepared, ballista kit which they were to assemble. The ballista could then be used to fire projectiles.

The class were then asked to design and build into the device some kind of 'stopping mechanism' which would vary the range of the projectile. They were then asked,

first: to optimise the range,

second: to calibrate the device in some way to provide a range finding mechanism.

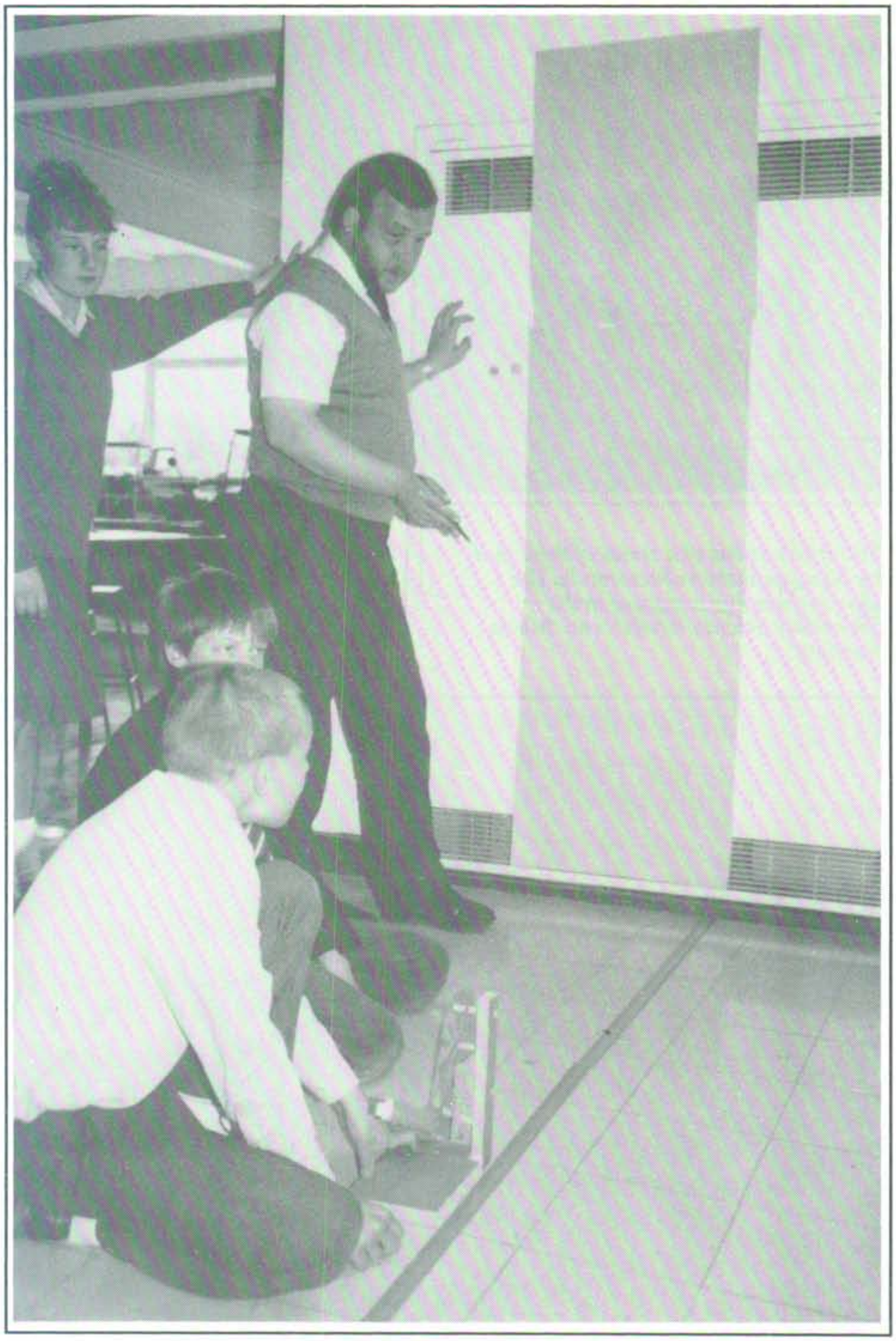


Alternatives were possible. One group enthusiastically developed an idea for a sliding stop which worked very effectively.

There were a number of extension activities which were then suggested to groups if time was available. These included investigating the relationship between the angle of release and the range of projection, and the relationship between the distance away from a wall and the height of the missile when it strikes the wall.

Two important features of this programme should be noted. First, we did not aim principally to develop craft skills. The class were expected to assemble the kit rather than build up from raw materials, to avoid a high demand on time and craft skill. Second, the key factor in the design was mathematical. The effective calibration of the device requires systematic recording of measurements, tabulation and interpolation, possibly with the aid of a graph. This kind of activity has often been exploited by MAP in developing mathematics from a technological context. The context provides motivation; the mathematics provides the optimisation of a design.

On the other hand the task has certain positive features for the technologist. Although the kit only required assembly, the design of the release mechanism, and the calibration of the device, are genuine 'design, make and evaluate' activities in the context of a clear need. The activity led to the successful creation of an



artefact in a limited period of time, and the children acquired skills of significance for future design activities.

The role of 'science' as such in the activity is arguable. Although the emphasis was technological, the activity nevertheless involved the processes of Science AT1 in the construction of fair tests, the controlling of variables and the analysis and interpretation of data.

Scientists would normally expect to see these skills deployed in the "exploration of science" ie. when investigastincgi entific phenomena. Nevertheless these same skills are important in experimental work in engineering and technology. Our view is that such contexts are as valid as the scientific one.

The task involved approximately 8 hours of class-time, drawn from Mathematics and Technology lessons. The key teacher taught the class for Technology and Mathematics. Support from MAP staff and an advisory teacher was also available, though we are confident that the activity was manageable without help.

The purpose of the activity was understood by the pupils and well suited to this age group. They were successful in constructing the device and released projectiles with due regard to safety! The construction of the 'stopping mechanism' generally followed the peg-design shown in the photograph.

The next step was to measure the range for different positions of the stop and, by trial and improvement, to find the maximum range. From this position, the angle of projection was systematically reduced and the range measured. The results were tabulated and in some cases plotted on a graph. Some groups interpreted the result in everyday English terms; for instance, noting that there may be two angles of projection possible for a given target.

The question of accuracy of the device naturally arises if the device is evaluated in terms of its ability to hit a target. This focused attention on the accuracy of the data. In fact, most groups initially averaged the distances given by a number of projections from a given angle and did not spontaneously explore the range of the data. The opportunity to develop the concept was missed in the hurly burly of classroom life.

Discussion and Conclusions

The lengthy list of statements of attainment from the National Curriculum document shown in the table at the end of this article, serves several purposes:

1. It validates the activity in the light of the aims of the separate subjects. It is our conviction that the true educational validity of a task resides in the response of the children to it and the learning that they gain from it, however it is clearly important to analyse such activities in terms of the statements of attainment in the National Curriculum.
2. It can be used as a diagnostic instrument. The gap revealed in the students' appreciation of the significance of the spread of data (i.e. the 'range' referred to in M/12/4/b) is an example of this.

3. It can be used to select a subset of the targets for formal assessment. One might, for example, define an extension activity for the students (or a group of students) such as 'Design and make a new scale to aim projectiles at a range of heights up a wall'.

We have grouped certain targets because they are assessed by the same evidence, this allows a more efficient assessment. Also, as was pointed out in[1], by doing this we are able to explicate some of the less precise statements of attainment in Mathematics (e.g. M1/4/a, *'Select the materials and mathematics to use for a task; plan work methodically'*) in terms of more detailed ones in Science and Technology at the same level (e.g. S/1/4/d, *'Plan an investigation where the plan indicates that the relevant variables have been identified and the others controlled'* and T/3/4/b, *'Work with others in the planning and apportioning of tasks'*).

The principal point must be, however, the success of the students in co-ordinating aspects of their Mathematical or Scientific knowledge in a Technological context. This is the starting point for the education of our future engineers and 'analytical' technologists.

References:

1 Maughan, C., Steeg, Williams, J.S.
Bouncing Balls at Trinity C of E High School, Manchester, 1989. — MAP Cross-Disciplinary Case Study No.2.

2. All references quoting Statements of Attainment are from the National Curriculum documents:
Mathematics in the National Curriculum, Department of Education and (1989)
Science in the National Curriculum, Science and the Welsh Office, (1989)
Technology in the National Curriculum, HMSO (1990)

This article is one of a series of three that are being published concurrently. The other two are due to appear in the 'Secondary Science Review' and 'Maths Teaching'.

	Target	Evidence
	Level 3	
T3/3/c	Use a range of hand tools and equipment, appropriate to the materials and components, with some regard for accuracy and quality.	Pupils built their devices to a satisfactory standard using saws, glue guns, drills, rulers and protractors.
S/1/3/d	Select and use simple instruments to enhance observations, for example, a stopclock or hand lens.	When testing their device pupils chose a metre rule or a 30cm rule to measure the range of projection. This activity thus provides one context, out of the many that will be needed, where this skill can be demonstrated.
M/3/8/b	Choose and use appropriate units and instruments in a variety of situations, interpreting numbers on a range of measuring instruments.	
T/3/3/d	Improvise within the limits of materials, resources and skills when faced with unforeseen difficulties.	One group chose to make a stopping mechanism of their own design using two triangular wedges as 'stops' (see fig 1). This did not work initially and required considerable adjustment.
T/4/3/a	Discuss their design and technological activities and their outcomes with teachers and others, taking into account how well they have met the needs of others.	Groups who effectively described the design, making, calibrating and testing of their device demonstrated, in this case, attainment of all of those statements.
T/4/3/b	Comment on the materials and processes used and how the task was tackled.	
S/1/3/1	Describe activities carried out by sequencing the major features.	
S/1/3/f	Record experimental findings, for example, *in tables and bar charts...*	
S/1/3/e	Quantify variables, as appropriate, to the nearest labelled division of simple measuring instruments, for example, *a rule.*	
M/9/3/b	Explain the work being done and record findings systematically.	
T/5/3/a	Use information technology to make, amend and present information.	Some groups used wordprocessors or graphics programs to enhance the presentation of their reports.
M/1/3/c	Make and test predictions.	'The further you pull it back, the further it will throw' — is a statement made by one of the groups that they then went on to test — and provided to be false!
S/1/3/a	Formulate hypotheses, for example, *'this ball will bounce higher than that one'.*	
S/1/3/c	Distinguish between a 'fair' and an 'unfair' test.	
S/1/3/h	Interpret observations in terms of a generalised statement, for example, the *greater the suspended weight, the longer the spring.*	
S/13/3/c	Be able to use simple power sources (electric motors, *rubber bands*) and devices which transfer energy (gears, belts, levers).	All groups demonstrated the use of elastic bands in the way described.
	Level 4	
S/1/4/f	Follow written instructions and diagrammatic representations.	All groups followed written and diagrammatic instructions to build their device.
T/3/4/e	Use drawings, diagrams and three-dimensional models, to assist making.	

T/3/4/b	Work with others in the planning and apportioning of tasks.	
S/1/4/d	Plan an investigation where the plan indicates that the relevant variables have been identified and the others controlled.	Examples of planning were observed in designing and in calibrating the ballista. In some cases these early plans were included in the final report.
M/1/4/a	Select the materials and mathematics to use for a task; plan work methodically.	
T/3/4/d	Adopt alternative ways of carrying out their plan when difficulties are encountered and recognise when help is needed.	Some pupils considered alternative ways of making 'stops' when meeting difficulties in the realisation of their design.
S/1/4/g	Carry out an investigation with due regard to safety.	All pupils achieved this.
S/1/4/j	Describe investigations in the form of ordered prose, using a limited technical vocabulary.	
T/2/4/a	Record their ideas as they develop.	Effective descriptions of how the scale was calibrated provided evidence for this statement.
M/1/4/b	Record findings and present them in oral, written or visual form as appropriate.	
M/7/4/a	Know the conventions of the coordinate representation of points; work with coordinates in the first quadrant.	Some groups used graph plotting software to plot points using coordinates.
M/12/4/b	Understand, calculate and use the mean and range of a set of data.	During the investigation groups spontaneously averaged data in order to record a 'best' single value for their tables and graphs. (However it was not a mean that they used, and they did not appreciate the significance of the range — see[1]).
M/13/4/c	Construct and interpret a line graph and know that intermediate values may or may not have a meaning.	Some groups drew a line graph or a curve through their data points.
S/1/4/h	Record results by appropriate means, such as the construction of simple tables, bar charts, line graphs.	
S/1/4/b	Formulate testable hypotheses.	
S/1/4/c	Construct 'fair' tests.	One group hypothesised that there were two different angles of projection that could be used to hit a given target, and then went on to verify.
S/1/4/i	Draw conclusions from experimental results.	

