I Know What I Taught, But What Do They Think They Have Learned?

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Practical Mechanics in Primary Mathematics is an Australian Research Council funded project investigating the learning and teaching of force and motion concepts in the upper primary school. While the project is primarily focused on practical activities and the mathematics necessary to model them, other aspects of learning are also being critically examined. One of these aspects is the extent to which the children can explain and defend their understandings of the physics involved in the activities. As part of the data collection the children are required to complete a reflective statement `What I found out from this lesson'. In this paper we look at the reflective statements that the children have written and analyse these with respect to what the children say that they have learned. The results of this study have implications for both teaching and assessment.

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Introduction

The answer to the question posed in this paper's title is found in the analysis of children's written responses to the prompt `What I found out from this lesson'. These self-assessments were part of the activities of the Practical Mechanics in Primary Mathematics project a two year research project funded by the Australian Research Council. The project, which commenced in 1995, is designed to investigate ways in which practical activities can be used to foster links between upper primary children's spontaneous concepts and Newtonian mechanics, and develop their skills in using mathematics to model real world phenomena.

National goals for Australian schools, as elsewhere, stress the importance of mathematics and science in enhancing children's understanding of the world and in developing skills to explain and predict everyday events (Australian Education Council, 1990; 1993). Mechanics was chosen as the focus for this project because the principles of mechanics underpin a wide range of other scientific disciplines.

The project is being conducted by the Australian authors of this paper in liaision with the mainly secondary student orientated, Mechanics in Action Project, directed by Julian Williams at the University of Manchester.

Background

Research indicates that children's spontaneous concepts in mechanics clash with accepted scientific concepts, are remarkably resistant to change and are already deep-seated by age 10 (Osborne & Freyberg, 1985; Gil-Perez & Carrascosa, 1990; Eckstein & Shemesh, 1989). Teaching experiments in mechanics have, however, emphasised secondary or tertiary students (for example, Thorley & Treagust, 1987; Williams, 1988; Savage & Williams, 1990; Thijs, 1992) rather than primary pupils (Marioni, 1989).

Vygotsky (1962) characterised children's scientific conceptions as developing downwards, while their spontaneous conceptions develop upwards, stressing the importance of the interaction between these, with spontaneous concepts enriching scientific concepts with meaning and scientific concepts offering generality to the spontaneous concepts. This is sometimes described as the vine metaphor.

Pines and West (1985) adopt the vine metaphor as a framework for considering different prototypes of learning situations presented by considering the extent to which the `upward and downward growing vines' clash or are congruent. They consider meaningful learning to take place when the two vines become intertwined, with the new scientific knowledge serving to make sense of the learner's world of experience.

Key research questions

The aim of the Practical Mechanics in Primary Mathematics project is to investigate ways in which practical mathematics activities can be used to nurture upper primary children's `upward growing' spontaneous concepts regarding force and motion, in order to establish links with the `downward growing' scientific concepts.

This research focuses on addressing those aspects of practical activities which impinge on the growth of concepts, and those aspects of classroom practice which promote their intertwining (see also Groves & Doig, 1995).

Research questions addressed by the project include:

●How do upper primary children interact with equipment-based practical mechanics activities?

In particular:
-which aspects of such activities are attended to by children?

-what mathematical and other techniques are used by the children to record and represent their experiences?
- what is the nature of the discussions between the children?

●To what extent does an appropriate program of practical mechanics activities, result in a shift towards more formal scientific concepts by the children, when teachers:
-have a knowledge of the children's spontaneous concepts;

-draw children's attention to the critical features of the activities; encourage effective recording and representation; and

-engage children in discussions which support theory building?

The practical activities

The first phase of the project, carried out mainly in 1995, examined how children interact with equipment-based practical mechanics activities. As part of this phase, a variety of practical mechanics activities were developed and trialled with small groups of upper primary children during the first half of 1995. These activities have as their focus the following broad concepts related to force and motion:

- speed as distance travelled in unit time;

- acceleration and deceleration;

- force as a `push' or a `pull';

- force is required to produce a change in motion; and

- friction and the force due to gravity are examples of forces which can produce deceleration or acceleration.

A number of the activities involve children recording the distance travelled in successive seconds (by a person walking, or a ball rolling on a track placed at different angles or covered with ribbon) and displaying their results in graphical form. A metronome is used to time one-second intervals, with different children marking positions of the moving object by placing small blocks on the floor or table. Paper streamers are then used to measure distances between the blocks to construct the graphs. Different experiments result in (approximately) uniform motion, acceleration and deceleration due to gravity, and deceleration due to friction. Another activity uses a ball with a built-in stop watch to explore vertical motion under gravity. Children also make (and later use) their own forcemeters from dowelling and elastic.

The use of streamer graphs is designed to facilitate the mathematical modelling of situations using the data obtained, but without the need to resort to complicated calculations or accurate graphing with pencil and paper.

From the activities trialled, those deemed most suitable for the age-group, most easily conducted in a classroom and most clearly focussed on the key force and motion concepts, were selected to form the basis for further classroom trials and finally for use in the experimental phase of the project that was conducted in 1996. The results of final last phase will be reported elsewhere.

The investigation

The final, experimental phase used a suite of eight lessons designed to give children active experience with both science and mathematical ideas. Among the force and motion concepts in these activities were speed, acceleration, friction, gravity, and the measurement of forces. The mathematical aspects of the activities included measuring, representation and interpretation of data and notions of accuracy.

The focus of this present paper stems from the research team's developmental work undertaken in upper primary grades with the assistance of classroom teachers. During this phase the researchers prepared written materials for both teachers and children. The teacher materials for each lesson included some science background pertinent to the focus of the particular activity, a guide to the setting-up and use of equipment, and a lesson plan to use as a starting point for conducting the lesson. The children's workbooks acted both as a guide through the various activities within a lesson, and as a place to record predictions, measurements, findings and inferences. It is in these workbooks that children recorded their responses to the `What I found out from this lesson' prompt that forms the data for this present paper.

The classroom teachers

The data are taken from work carried out in two classrooms within the one school in Melbourne, Australia. The school is situated in a middle class area and is held in good regard by the local community. In particular, the staff have a reputation for conducting a good science program as part of the school's curriculum. The teachers involved in this developmental phase of the project were volunteers, and were given the freedom to conduct the lessons as they felt best for their children with, however, the understanding that the key aspects of each lesson should be addressed as the research team required. In each of the eight lessons the key aspects were that the children engage in practical activities often in groups working independently of the teacher and that discussion be encouraged between the children and the teacher on all aspects of the lesson. Moreover, the lessons had been designed in such a way that, typically, in each lesson some new concepts were introduced, while others were revisited and some were possibly suggested as being likely to have become established. There was discussion with all teachers in the project regarding the fact that, for many of the concepts, it was not expected that closure would be acheived in a single lesson (if at all for many children). The degree to which each teacher was able to accommodate these requests varied according to their personal `teaching style'.

The style of Teacher A could be described best as `organic' rather than lead the discussions, she allowed it to ebb and flow and follow the children's ideas. Children were encouraged to reflect upon their experience without the teacher attempting to acheive closure for each lesson. Despite her claim that her own science knowledge was not particularly strong, she had a good understanding of the lesson content partly because after the first lesson she decided that she needed to prepare more thoroughly and was prepared to invest the time and effort required. She was well organised for working with the equipment and the practical activities.

Teacher B believed, correctly, that her understanding of science concepts in particular the science involved in these lessons was better than most. Possibly for this reason, she appeared to devote less time to preparation although both teachers often relied on whoever `went first' to help the other one prepare. She appeared to place much less emphasis on organisational aspects of the lessons (which sometimes led to difficulties with the equipment and the conduct of the activities). Despite a generally less structured classroom, aspects of her teaching style could be described as `conventional' in particular her apparent need to achieve closure for each lesson. While her approach to the lessons was in the format outlined by the research team, discussions often led to a recapitulation of the `correct' science, with `correct' ideas from the children being emphasised.

Although different, their approach to teaching in general was remarkably similar in many respects; children mostly worked in groups, lessons were planned to be of interest to the children, and a broad curriculum was taught. Differences were to be found mainly in the sense that while Teacher A was prepared to allow the children to learn, Teacher B appeared to focus on teaching the children.

The children

The children in these two classes attend a warm, friendly school and are typical of children from the middle class homes in this part of Melbourne. The children were assessed prior to undertaking the project lessons using a modified form of the Tapping Students' Science Beliefs (TSSB) unit on force and motion called Skateboard News (Doig & Adams, 1993). This instrument contains twelve open response format questions focused on speed, acceleration, friction, gravity and resultant forces. Table 1 shows results for both classes on this assessment.

Table 1
Tapping Students' Science Beliefs: Results for Class A and B

	Class A (N=30)	Class B (N=29)
Range	8 - 30	11 - 33
Mean	18.4	18.4
Standard Devn	6.29	5.54

Obviously there are differences between individual children, but collectively the classes appear to be well-matched with respect to the science concepts that form the foci of the project lessons.

The lessons

The two lessons that provide the data for this paper were chosen as examples of the types of equipment-based science lessons used in the project; both lessons involve children working with equipment, measuring, making and testing predictions, and discussing their experiences. The structure of the lessons varied, but one essential feature that remained constant was the emphasis on discussion.

Both lessons required the children to work in groups, in one case in groups of six, in the other case in pairs. The outlines of these lessons given below are divided into four sections: a summary of the lesson; the foci of the lesson in terms of science, mathematics and practical skills; the concepts involved; and the suggested discussion points. Since these lessons form part of a larger suite of lessons, there is naturally an overlap in some aspects of these outlines.

Lesson 1 Rolling balls

Summary. In this lesson a ball was rolled down a short ramp, onto a flat track. Two different release heights on the ramp were used. The children marked the position of the ball on the flat portion of the track every second, and used these marks to make strip graphs from paper streamers. The streamer lengths equalled the distance travelled by the ball in each second, and provided a possible way of determining the speed of the ball.

Foci. Setting up equipment according to instructions and conducting experiments relatively independently in groups is often considered difficult for children in the primary school. Thus, in terms of practical skills, working as a group to measure the speed of a ball rolling on a smooth flat track was a primary focus of this activity. (This was the second of the eight lessons and the first had been a class lesson.)

Children often focus on the length of individual columns that form simple bar graphs. In the case of this activity, children in previous trials had attempted to explain small differences in the lengths of the streamer strips, that form the graphs of the ball's speed, by complicated arguments relating to bumps in the track. By repeating the experiment and getting different patterns of strips, it was hoped that children could be encouraged to focus on the trends in the data rather than the individual strips. Children might also see that repeating experiments can help to minimise error in measurements.

The major science focus was on the speed of a ball rolling on a smooth flat track when released from two different heights. The mathematical notion of average was also one of the foci.

Concepts. Speed as distance per unit time requires children to recognise that the strip lengths represent the distance travelled by the ball in one second. The fact that the ball goes faster when released from higher up a ramp allows children to firmly associate longer strips with faster motion and see that the further the distance travelled in a given time, the faster the motion.

This lesson aimed to develop intuitive notions of `average'. Children who offered `the formula' for finding averages were to be encouraged to `make a guess' at how big the average would be and decide which, if any, of the strips had `average length'. It was also suggested that the notion that the strips should somehow `balance out' around the average could be introduced.

Discussion points. These included:

- What do the graphs tell us about the way the ball moves?

- In what ways are the graphs the same?

- In what ways are they different?

- Why is it useful to repeat the experiment and produce more than one graph?

- Could we use the graphs to find out about how fast the ball was moving? How?

- Why do you think the ball goes faster when we release it from the blue [higher] mark?

It was anticipated that some children might introduce gravity and friction into the discussion regarding why the ball gained speed on the ramp and lost speed on the flat track. While this was to be encouraged, teachers were warned that most children would not describe it in this way.

Lesson 2 - Measuring forces

Summary. This activity involved the children in making a simple measurer (Forcemeter) from wood and elastic to measure small forces. These Forcemeters were calibrated by the children in one Newton steps, up to five Newton. These Forcemeters were than used to explore the effect on motion of two unequal forces pulling in opposite directions. Some aspects of the effect of equal forces on motion were also explored.

Foci. Constructing and calibrating measuring devices according to instructions was the first focus of this activity. Once the measurer (Forcemeter) was completed, the exploration of the relationship between unequal forces and motion was possible.

The role of unequal forces in producing motion was the major focus of this activity. The distinction between no acceleration and no motion in the presence of equal forces was not attempted.

Concepts. The fundamental ideas in this lesson are that unequal forces on a stationary object definitely produce motion, and that an object that is not moving must have equal forces on it. This is not the same as equal forces producing no motion! At this age level it is expected that the logic involved here is too difficult.

If we know which is the greater force acting on an object at rest, then we can predict the direction of the motion. This is intuitively obvious, but may not previously have been fully articulated by the children.

Discussion points. Children have a range of ideas about what a force is. The discussion aimed to establish that, despite subtle differences, forces can generally be described as pushes or pulls. Discussion of everyday use of the word `force' was encouraged. For example `the police force' is a different use of the word.

Other points included:

- measuring instruments need to be calibrated;

- objects move in the direction of the net force;

- forces in balance produce no change in motion (in this case, the object remains stationary); and

- no motion indicates that forces are in balance.

Many people believe that when there is no motion there are no forces acting on an object. It was not expected that children would change to a more scientific idea at this stage.

Data source and analysis

The two lessons selected for this analysis were chosen because they represent two different types of lesson organisation. Lesson 1 had the children in groups of six all of whom were involved in the one activity, making group graphs of the motion of a rolling ball. Lesson 2 on the other hand involved a pair of children constructing a Forcemeter for each child.

The self-assessment mechanism was a request that the children write in their workbooks a response to the prompt `What I found out from this lesson'. There were a possible 147 responses available for analysis; however not all children wrote a response to each lesson, and of those who did, some responses were uninterpretable. This reduced the total number of responses available for analysis.

The method adopted for the analysis was that used in the construction of the Tapping Students' Science Beliefs (TSSB) conceptual understanding continua (Doig & Adams, 1993) where it is explained in more detail. Essentially the analysis involves reading the entire set of responses and, on the basis of their focus, putting each response of similar nature into one of a set of categories. These categories are necessarily mutually exclusive. Typical categories could include responses that contain references to the influence of gravity, or responses that contain reference to the need to work together as a group. This process (of reading and categorising) is repeated until a set of categories is established that can accommodate all responses, and with which the analyst is satisfied.

Some modification needs to be made to this approach for open-ended responses as many responses contain elements of more than one category. For example `The slower the ball is the shorter the strip is' was part of a response that also contained `Some people put the blocks down in the wrong place'.

It is clear that the two parts of this response have different foci and thus the whole response was broken down into portions that were then allotted to appropriate categories.

A further modification is necessary when a response contains separate responses within one category. That is, the overall response contains two qualitatively different responses. For example `That a strip represents [how far the ball rolls in] a second and how [to] measure how fast a … ball is going' clearly has two distinct references to the mathematical aspects of the activity.

When these modifications were made to the categorising of the responses, the data set contains 409 separate references to be categorised.

Analysis One

The first reading of the children's responses from the two selected lessons showed four possible categories of response.

The first of these categories was formed by those responses that contained social comments. A response typical of these is one that lists those in the group who worked together, or one where the need to be co-operative is mentioned.

The second category was that of comments on the practical aspects of the activity, such as the difficulty of working with the equipment.

The third category was of those responses that mentioned aspects of either the mathematics or science that are best described as factual observations. An example of a response in this category is one that involves a defintion such as speed is distance divided by time.

Finally there were those responses that mentioned conceptual aspects of the activity. A typical response in this category is `pulling something is a force and is very different from mass'.

Figure 1 describes each category and illustrates it with a sample response.

Figure 1: Response categories used in analysis one

The results of this first categorisation are summarised in the Table 2, where all numbers are percentages of the total number of responses and the numbers are rounded to the nearest whole number.

Table 2
Analysis One: Percentage of responses in each category

	TEACHER A		TEACHER B	
LESSON	1	2	1	2
CATEGORY				
Social Comments	10	10	5	4
Practical Aspects	26	33	34	30
Factual Observation	23	22	21	23
Conceptual Underst	40	35	39	43

At first glance it is possible to see that this analysis of the children's responses, under two different lesson organisations, remains basically stable for each teacher. Nevertheless, Teacher A's children made more responses in the `Practical aspects' category for Lesson 2, which involved constructing a Forcemeter. TeacherB's children gave more Practical Aspects responses for Lesson 1, which used simple pieces of equipment, but in an unfamiliar way (rolling a ball down a track while timing it).

There are some distinctions between the number of responses by the children in the `organic' teacher's classroom (Teacher A) and those in the `conventional' teacher's classroom (Teacher B). The major distinction between Teacher A's children and Teacher B's children is in the percentage of Social Comments responses they gave; twice as many. Whether this is attributable to the social ambience encouraged by Teacher A in her classroom is impossible to tell; there is nothing suggested by observations of the class that Teacher B's classroom was unsociable. In the Practical Aspects category there is a slightly higher percentage of responses from Teacher B's children. This is probably a result of the teacher's emphasis on obtaining a `correct' result.

In the other categories the proportions of responses are approximately the same for both classes, with the main difference being in the percentage of responses in the Conceptual Understandings category.

Analysis Two

However the categorisation of Analysis One is too simplistic, since, for example, it puts together all responses that mention conceptual understandings. Thses types of responses fall into two distinct subsets: those that focus on mathematics and those that focus on force and motion. A second categorisation was therefore undertaken, with the responses in the original Conceptual Understandings category divided into two sub-categories: Mathematical Concepts and Science (force and motion) Concepts. Figure 2 describes each of the additional categories provided by Analysis Two, together with sample responses for each category.

Figure 2 Additional response categories used in Analysis Two

The resulting analysis is presented in the Table 3.

Table 3
Analysis Two: Percentage of responses in each category

	TEACHER A	TEACHER B
LESSON	12	12
CATEGORY		

Social Comments	1010	5	4
Practical Aspects	2633	34	30
Factual Observations	2322	21	23
Conceptual Understandings			
Maths	250	102	
Science	1535	2941	

The most striking feature of the second analysis is the categories that have low response rates, and the inconsistency of these across lessons. Lesson 2, where the children worked in pairs to make Forcemeters, provoked almost exclusively, responses that were focused on science concepts. While the response pattern is much the same for the children in both classes for Lesson 2 i.e. negligible mathematics responses there is a remarkable difference in the ratio of mathematics to science responses between the classes for Lesson 1. Teacher A's class had almost twice as many maths responses as science ones, while TeacherB's class had almost three times as many science responses as maths ones for the same lesson. This again was possibly the result of Teacher B attempting to achieve closure on the science concepts as part of the class discussion.

Analysis Three

Again the data were re-categorised to isolate those responses that were `correct' (scientific) from those that were `incorrect'. The results of this analysis are presented in Figure 3. The symbol (+) indicates a response categorised as `correct', while (-) indicates a response categorised as `incorrect'.

The results for Analysis Three, the last, are summarised in Table 4.

This final analysis, sub-dividing responses into those `correct' and those `incorrect' appears to provide most information particularly for Lesson 1 where children's responses vary greatly both between and within classes. Within classes Teacher A's children, who were less directed, divided almost evenly in their mathematics response pattern (`correct' or `incorrect') while in their science response pattern they were mainly found to be `correct'. In Teacher B's class the children overwhelmingly responded `correctly' in mathematics, but were divided about evenly in science. In both classes Lesson 2 produced almost a complete set of `correct' science reponses and no mathematics responses.

Figure 3 Additional response categories used in Analysis Three

Table 4
Analysis Three: Percentage of responses in each category

	TEACHER A	TEACHER B
LESSON	12	12
CATEGORY		
Social Comments	1010	5 4
Practical Aspects	2633	34 30
Factual Observations	2322	21 23
Conceptual Understandings		
Maths (+)	12 0	102
Maths (-)	13 0	00
Science (+)	1435	1641
Science (-)	10	130

The differences between the classes is most evident for Lesson 1, as has been mentioned in the results of Analysis Two. However Analysis Three brings to light that not only do the two classes differ in the focus of their responses, but also in the ratio of `correct' to `incorrect' responses. Teacher B's class, who made twice as many science responses as Teacher A's class, were almost evenly divided between `correct' and `incorrect' responses, while Teacher A's class, with only fifteen responses, were in the ratio of fourteen `correct' to one `incorrect'. The reverse of this situation is true for the mathemastics responses, where Teacher B's class had no `incorrect' responses.

Overall themes analysis

Major themes emerging from the responses are those to be found within the responses and those that are inferred from the responses. Those that are to be found within the responses themselves are discussed first.

In terms of the Social Comments category of response the major theme to emerge was that the children's responses suggested that they found the activities easy to do. In terms of affect this is very encouraging.

In the responses categorised as being related to Practical Aspects of the lessons, two main themes emerge. First that while conducting practical activities of the type outlined here presents some difficulty in the normal classroom, children's responses in general suggest that upper primary children can cope with equipment-based science activities. This is aided by the fact that the classroom teachers modified their classroom arrangements to accommodate the lessons and that the workbooks for the children included instructions on setting up the equipment and carrying out the activities. A pattern of using workbooks in parallel with teacher direction and class discussion emerged, with most children carrying out the required tasks quite successfully. Children became adept at using the equipment (stop watches, metronome, forcemeters, etc), developing the skills of measuring quantities (time, distance, force etc) and recording data (tables, graphs, force diagrams etc).

The other main theme to emerge from the children's responses in this category is that of accuracy. Placing the block at the precise position where a ball is when the metronome ticks proved to be a very difficult task and, as a result, there were many inaccuracies in the data. While these were usually not critical in assessing whether the ball was accelerating or decelerating, in the case of constant motion these inaccuracies were critical. Textbook examples of data tend, a priori, to support the expected results of an experiment that is data are manufactured to give the results, known in advance by the teacher and supposedly discovered by the children. In practical activities there is no such elegance and awkward data is always present. Children could agree that the data was suspect, but at the same time use it to provide an apparently precise description of the motion of the ball. These attempts, apparently to force one-to-one mappings of the data to `reality' were reminiscent of the `pattern-forcing' recorded by Pereira-Mendoza, Watson and Moritz (1995) with respect to graphs.

The categories containing the responses to Mathematical Concepts (`correct' or `incorrect') of the activities are less well-defined than those in either the Social Comments or Practical Aspects categories. However one theme focused on averages. Sometimes the term is used correctly, but more often than not incorrectly. For children of this age in Melbourne schools, averages are usually not taught conceptually; if they are taught it is usually by an `add and divide' rule. In the case of these children the strip graphs provided an ideal opportunity for learning about averages from a conceptual standpoint, as well as seeing their practical use. The evidence of the children's responses suggest that this opportunity was lost.

In the Science Concepts categories, the relationship between the magnitude of a pair of opposing forces and the resultant motion is the dominant theme. Not only that but it is almost universally, correctly reported. The other main theme was thae relationship between the speed of a rolling ball and the distance it can travel in a fixed time (or variants of this idea). This theme was addressed differently by children from the two classrooms.

Underpinning the whole of this research is the belief that children's spontaneous conceptions not only need to be listened to and acknowledged, but that there is no easy short cut to developing more scientific conceptions. A major difficulty, when attempting to develop materials for classroom use by others, is the need to adequately convey the thrust of the lesson while at the same time retain sufficient flexibility to allow children to actively pursue their own lines of thinking. Coupled with this is the widespread notion that `good teaching' must always involve achieving some form of closure. In the case of Teacher A and Teacher B, the former was able to resist closure, while Teacher B felt it necessary to `sum up' the experience and knowledge from the lesson. Which of these is the more successful tactic one must judge from the children's own responses to what they think they learned.

Conclusions

While it is acknowledged that the data source may be considered slight, being taken from only two classrooms, the responses to the self-assessment given by the children are nevertheless revealing. Bearing in mind the descriptions given earlier of the teachers, it would seem reasonable to suggest that the following conclusions can be drawn from these data.

Children can comment and provide valuable insights into what they think that they have learned. While not the results of formal assessment, the children's self-assessment does provide a rich source of information for teachers. In some instances children have revealed clear understandings of what they have learned, and in other instances quite the reverse. While self-assessment does not aspire to completeness or standardisation, it is simple to implement and justifiably rewarding.

From the children's responses it is clear that upper primary children are capable of using and learning from equipment-based lessons in science given appropriate support. Note that these lessons were those in which the children were actively involved in the experimentation and not merely an audience for a teacher demonstration; the responses children may give to a self-assessment in the latter case may not be so encouraging!

Most teachers believe that children should be led to some form of closure at the end of a discussion or lesson. Based on the responses of these children, one class of whom were working within this paradigm, and one class who were not, it appears that closure in discussion does not produce appreciably better understanding for children than does discussion which does not lead to closure. This is a facet of classroom practice that obviously needs to be the focus of carefully designed research.

On the evidence from these children teachers who use different classroom organisations can use the same equipment-based activities in science, when they modify them to suit their `teaching style'. The suite of activities created for the Practical Mechanics in Primary Mathematics project was designed to be modified to suit different classrooms and still provide effective experiences for children, as these two typical lessons demonstrate. Equipment-based science lessons with different group structures can be effective for most children, within varying classroom organisations, has only be shown by these data to be true for pairs of children and groups of six. Further investigations are required to be able to generalise further.

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