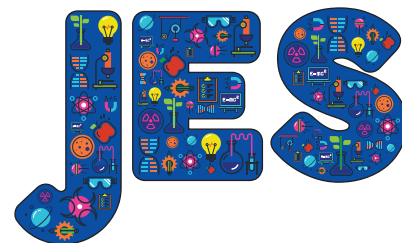


Exploring some simple machines and their applications



● Robert M. Ritchie ● Sophie D. Franklin ● Tim G. Harrison
● Peter Sainsbury ● Paul Tyler ● Michele Grimshaw ● Dudley E. Shallcross

Abstract

Open-ended investigations, supported by class discussion, can lead to a deep exploration of a topic. Here we discuss this idea using a set of wooden models or machines. Each model has the same elements: a handle that can be turned but with a different effect on turning for each model. Working with Year 2 and Year 6 (ages 7 and 11) classes illustrates the different manual and oral capabilities between younger and older age groups. The younger age group showed that they are still able to articulate quite sophisticated concepts using these models. The models can also be used in a range of activities and, in particular, in cross-disciplinary studies.

Keywords: Argumentation, machines, pushes and pulls, open investigations

Introduction

The PSTT founded its College of outstanding primary school science teachers (Shallcross *et al*, 2015) with a challenge to its new Fellows: have a box of wooden models and explore how they can be used in a primary school setting. The set of models developed are described in detail by Sophie Franklin (Franklin, 2013) and some will be briefly described in this paper. There are a myriad of machines that convert circular motion into other forms of movement. An example of this is the

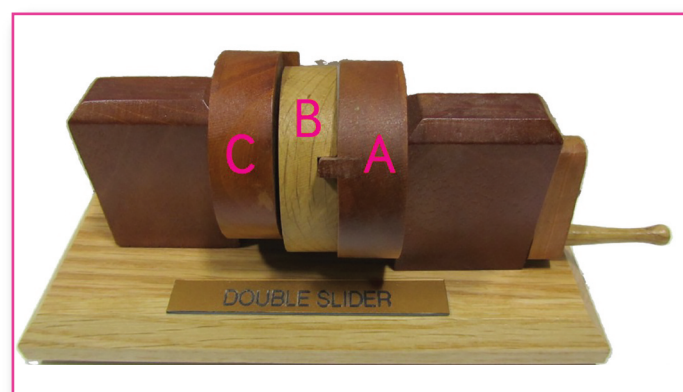
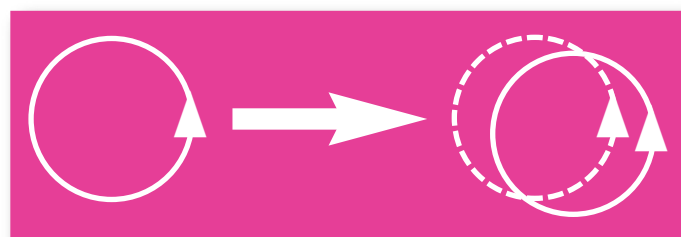


Figure 1: Double slider model system.

Figure 2: A pictorial version of the operation of the double slider mechanism: rotating wheel A causes wheel C (dashed wheel), which is offset, to rotate in the same direction and at the same speed.



so-called double slider gear system (see Figure 1). Here, rotating the handle causes wheel A to rotate and, with it, coupler block B. As block B rotates, it is coupled to wheel C, which is offset from wheel A, and can now rotate at the same speed as wheel A.

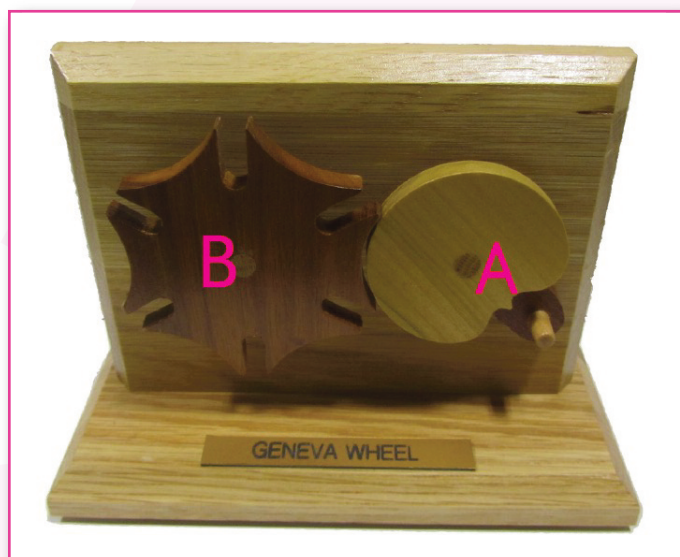
In pictorial form, the motion can be summarised as in Figure 2. It is a simple machine to operate and it is also simple to understand what it is doing. John Oldham designed this system to solve a problem with a paddle steamer design, but it also now has several modern-day applications.

The Geneva wheel is another example of a rotating system, where the complete continuous rotation of wheel A causes partial or intermittent rotation of wheel B. For wheel B to undergo a complete rotation, several complete rotations of wheel A are required (see Figures 3 and 4).

The Scotch Yoke (Figure 5) transfers rotation into vertical (up-and-down movement – see Figure 6).

Peter Sainsbury (Sainsbury, 2011) has reported the first use of these models, adopting an approach similar to Mitra and Rana's 'hole-in-the-wall' project (Mitra & Rana, 2001; Mitra, 2003). Mitra and Rana set up a computer interface through a hole-in-the-wall of their centre in India and, without instructions, observed how children interacted with the computer. These workers observed remarkable

Figure 3: Geneva wheel model system.



progress made by the self-taught children. In a similar approach, Sainsbury left the models in an accessible place and observed primary school children of all ages playing with, exploring and observing the models. Their discussions about the models, how they worked and what they did were noted. Sainsbury wanted to add a challenge to the children's exploration. This was provided by some Year 4 students (8-9 years old) who wanted to know where these models could be used in real life examples. The school displaying the models is in close proximity to an army barracks and some of the children's inquiries yielded real life examples from their family members serving in Afghanistan. A very diverse list of uses was compiled by these children.

The full set of models is described in detail by Franklin (2013), but the 12 models used were: the double slider, the Geneva wheel, the fast return actuator, the eccentric, the cam and follower, the self-conjugate cam, the scotch yoke, the

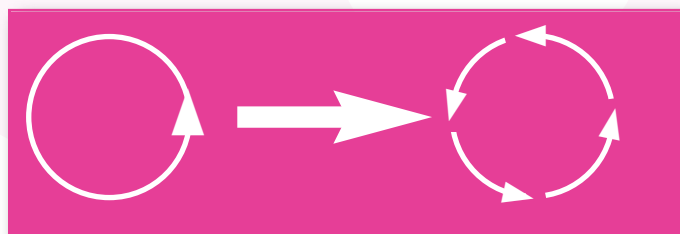
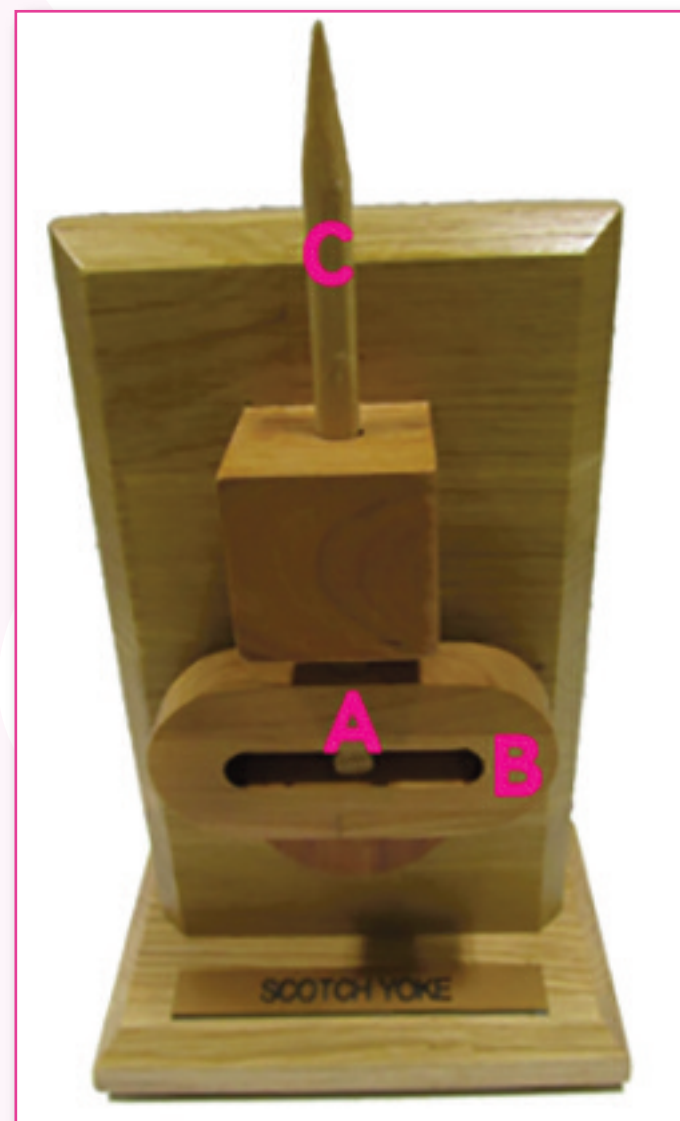


Figure 4: A pictorial version of the operation of the Geneva wheel mechanism. Rotating wheel A for one complete revolution causes wheel B (dashed wheel) to move around a fixed amount and stop. In order for wheel B to complete a full rotation, several full rotations of wheel A are required.

Figure 5: Scotch Yoke wheel model system.



intermittent drive, the double universal joint, the roller gearing, the loose link coupling and the positive action cam. Based on these preliminary explorations, we surveyed how these models were used by Fellows (teachers) of the PSTT College and also trialled them in local primary schools as part of an undergraduate final year project. In addition,

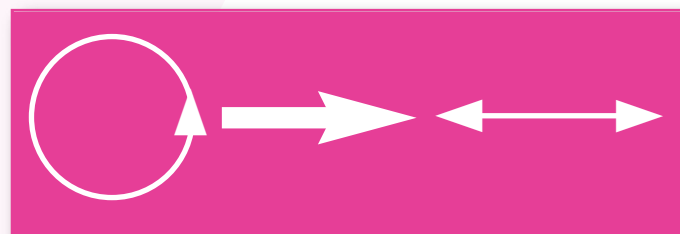


Figure 6: A pictorial version of the operation of the Scotch Yoke mechanism. Rotating wheel A one complete revolution causes the oval-shaped wheel B to move up and down and, being connected to the pointer C, this moves up and down.

in this paper we focus on how they were used in different ways for a Key Stage 1 year group (aged approximately 6-7 years) and a Key Stage 2 year group (aged approximately 10-11 years).

Key Stage 1 group

Each session with a new class began in the same way. Given that there were 12 different models and that more than one set was available (not always the case for teachers), all pairs of children had a model to explore all of the time. One of the problems with open explorations of this kind is the availability of the resource and this can itself hamper exploration. For the first 15 minutes or so, the children were asked to explore the models and share them between the groups on their table. In this way, children could explore 2-3 models each. At the end of this time, they were asked to describe the models and their actions to each other. For many models, the children could not only describe the action of the model, but could also describe whether the resulting motion was faster or slower than the rate of their handle-turning to operate the model. The children rotated around the tables so that they had time to explore all the models.

They were then asked to group the models and justify their reasons. If rules for class discussion are established (e.g. Mercer *et al*, 2003), this can be a very fruitful exercise, even with young learners. There are in fact myriad ways that these models could be grouped and a wide range of groupings were suggested by the children, showing that they had grasped the cause and effect nature of most of the models.

Other discussions included how many times one would have to rotate wheel A in the Geneva wheel to make wheel B rotate once, the different types of wood that were used to make the models, and whether other materials could be used to construct them. The children were asked whether they had seen these machines in real life or whether they could imagine where they were used. The two models described were often mentioned by the children; in the case of the Geneva wheel, there were various suggestions such as a shutter system, opening and closing something or a timing device (which is one of the uses). They were then given a set of pictures and asked to match them to the models, with an example set shown in Figure 7.

Some of the children were unfamiliar with several of the objects in the picture, but a few were able to identify the correct model.

Key Stage 2 group

Understandably, the pace of the lesson was quicker for the older age group, in that they explored and described the models in a shorter time span than the Key Stage 1 groups. In addition, when they were asked to group the models, they were much more assertive in their decisions and were seeking the answer about which was the 'correct' grouping from the leader. The leader stated that, provided the grouping could be explained and justified, it was 'correct' and that there were many groupings.

When presented with the pictures of real life objects, the older pupils were able to identify most of the objects and could, overall, pair the models with pictures. A final challenge set was for the children to build one of the models using a Lego modelling kit available at the school. Although the



Figure 7: Illustrative objects that could use some of the models in the set: a toy merry-go-round, a watch, a steam engine and a washing machine.

children took a while to decide on which model to reproduce and needed to figure out how to use the Lego modelling kit, most groups managed to complete a good representation of the wooden model. Such an exercise illustrated several aspects: firstly, it demonstrated that the children possessed a range of fine motor skills; secondly, the students demonstrated that they understood what the wooden model was doing and could reproduce it using a new model system; and they also demonstrated collaborative skills and a variety of argumentation and reasoning skills.

The teachers commented that they had never used the Lego kits before and that the children had achieved a great deal in the workshop and had been on task for the majority of the time. When asked whether they enjoyed the workshop and whether they learned something new, there was strong agreement. Having access to such a set of models, or even multiple sets, is a problem for most schools, but several of these models can be made simply and cheaply using everyday materials.

However, the point this illustrates is that, given an appropriate stimulus, children at primary school can carry out very sophisticated investigations largely unaided. Children need time to explore and investigate and they do need a teacher/leader who can provide support through questions to stimulate investigations. Extension activities worked well with both age groups and both girls and boys were engaged in these activities. Just as Mitra and Rana (2001) discovered, children can work things out for themselves if they are given enough time.

Fellows' feedback

In a primary school in Glasgow, the models were used to foster curiosity about engineering in a Scottish primary 7 (11-12 years) science club. The models were set out as the pupils entered the room and they worked in small groups to discuss each model in turn. There was no intervention from the teacher, who simply observed them working and listened to their discussions and questions. Initial discussions focused around trying to describe the movement of each of the models, e.g. *'This one could make something go up and down when you turn the handle'* (Scotch Yoke) and *'This one moves the movement across'* (Loose Link Coupling). Pupils were then directed to draw diagrams of the

models and use arrows to show the operators' actions and how the machine changed the input motion into the output motion. During this activity, pupils were asked to suggest possible uses for the machines. Although they were able to accurately describe the motion, they found it very difficult to suggest possible uses due to a lack of background knowledge. They were then asked to choose two of the machines to research further at home and see what applications they could find.

The following week pupils shared their research with their groups and the discussions centred round real life applications of each machine. Many of the examples were accompanied by short video clips or gifs that showed the machines in action. Being able to see the machines in action helped pupils to visualise where each machine's motion could be applied.

The final task was for groups to use the knowledge and understanding they had gained to design a new application for some of the machines.

Feedback from the science club pupils was overwhelmingly positive and they all reported that having models of the machines that they could manipulate and observe had helped them to understand how they worked and could be used.

It was clear from observing the pupils and listening to their discussions and questions that the models had challenged their thinking and made them curious about how the machines were used and how they were developed.

Other uses

Fellows (teachers) reported a wide range of activities that were prompted by these models. Here are some very specific examples that they mentioned:

'We've been using them mainly in Year 5 as we were making cams in our space unit and the children have loved them.'

'The children explored the different models and mechanisms, drew detailed diagrams of how they worked, including direction arrows. They then began to think about how the various mechanisms could be incorporated into a design of their own fairground

ride. They had to decide which model was most suitable to incorporate into their design and why.'

They also mentioned more cross-disciplinary uses, as shown by the quotes below:

'The models were used as part of a lesson on Victorian technology and the industrial revolution.'

'Our teachers have used them in art work, looking at textures, shapes and colours of the wood.'

Some children researched the model mechanisms and not only identified where they were used, but also their history.

Summary

Machines are a challenging subject at primary school level. This study suggests that, given an appropriate resource and the opportunity, children of a wide range of ages can make significant advances in their understanding of some quite complex machine mechanisms. They can compare different machines and group them in a wide range of ways using obvious and less obvious, but no less valid, sorting criteria. Progression of the investigation can take a number of forms, but challenging them to think about and match the machines with real life machines produces lively and progressive discussions. Having the confidence to support open-ended learning is a challenge but, in this study, the progress registered by the children illustrates that it can be a significant benefit to learning.

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Rob Ritchie was a STEM ambassador during this work. **Dr. Sophie D. Franklin** is Cluster Director of the Primary Science Teaching Trust and a research associate in Science Education at the University of Bristol. **Tim Harrison** is Director of Outreach for Bristol ChemLabS, the Centre for Excellence in practical chemistry teaching in the UK, based at the School of Chemistry, University of Bristol. **Peter Sainsbury** is a primary school teacher, Fellow of the PSTT College and adviser to the PSTT Cluster programme. **Dr. Paul Tyler** is a primary school teacher and Fellow of the PSTT College. **Michele Grimshaw** is a retired primary school teacher, Fellow of the PSTT College and area mentor for the PSTT College. **Professor Dudley E. Shallcross** is a Professor of Atmospheric Chemistry at the University of Bristol and also CEO of the Primary Science Teaching Trust. E-mail: dudley.shallcross@pstt.org.uk

