A Meccano® model of approaches to teaching mathematics

Judith McCullouch uses Meccano® with initial teacher education students to explore their flexible use of pedagogical approaches.

As teachers of teachers, we are keen to impress on our students (ITT and CPD) that teachers who are effective at teaching adopt a range of pedagogies that put the learner at the centre, combined with confident and flexible teaching (Williams, 2008). We teach them, for example, that Murphy (2003 p.125) considered that there are two forms of pedagogical realism; "objective" in which the teaching will lead pupils to the one way and "subjective" in which the pathway to the solution may be variable and even idiosyncratic. Another position is to distinguish between learning a series of procedures and learning through building up conceptual understanding, creating the potential for strategic thinking. Amongst the various terms used, Skemp (1976 p.14) described "instrumental" and "relational" learning and Askew et al (1997 p.3) "transmission" and "connectionist".

As teachers of teachers we feel we should adopt the principles described above with our students. A device that has proved useful to examine mathematics teaching and to explore research about mathematics teaching is the model construction system Meccano®.

> It is after all, a very versatile constructional medium. Almost any mechanical device can be built with it, from structures, to complex working cranes, automatic gearboxes or clocks. […] Model realisation using Meccano® is limited mainly by the imagination and ingenuity of the builder (Meccano®, 2016).

Consider building a lifting bridge. This was used to offer three possible scenarios for modelling which were given to primary PGCE students in three groups. Group 1 was given sets with the exact parts and instructions to build a bridge. Group 2 was given a box of parts (one missing) with photocopied (black and white) instructions and the group 3 was given a box of parts without instructions. Within their groups the students worked in pairs or threes. They were asked to build a bridge, then note down their thoughts on what and how they learned and how they felt. Following whole class discussion, they then noted how this activity related to theories of learning and teaching mathematics.

For group 1 the principle is that, with a little concentration, some reading and fine motor skills, the bridge can be built to a high standard, matching the illustration on the box, thus achieving a strong sense of accomplishment and satisfaction. Having completed the task, the child might either leave it on show or take it apart. The child may acquire several such sets and hence this will create variation in the construction tasks through building each one in turn. The complexity of the models may also increase moving on from just joining parts together to the use of cogs and gears, demonstrating the interconnectedness of cause and effect. The child might work with a friend, which may speed up the construction if they are able to work collaboratively or may reduce the effectiveness of the build through disagreement or lack of cooperative skills. This scenario might be sufficient for the child who does not aspire to more through choice, lack of desire or lack of knowledge of other possibilities.

Some responses from this group are tabulated below:

What I learned	*Follow instructions; lay out/organise pieces first; take time to identify correct pieces.* *Work in pairs.* *Instruction really helpful; be careful when constructing; not to rush.* *Not everyone works the same way; even in a pair, one sorted, one got on, which is a potential source of frustration.*
How I learned	*Used instructions; talked; taking turns; be patient.* *Mistakes: cogs not touching and had to take apart and rebuild; used wrong piece even though clear in the instructions.*
How I felt	*Pleased to complete; confident it was right; pleased all pieces were there.* *Happy to be in the group with all bits and instructions; no hope without instructions.* *Needed to finish; competitive, wanted to finish first.* *No need for much talk, discussion; no creativity.* *Enjoyed task, was surprised.*

If working with scenario two, it could be reasoned that the children will be more challenged to build the original models as they will have to find the parts but they will still have the security of the instructions. They may even be able to make modifications either to accommodate lost pieces or to explore other possibilities through active engagement. The uniformity of the parts would support the developing creativeness offered in this situation. If working with a friend, they may still not work together well, and indeed, have more opportunities for disagreement with the wider range of options. However, the potential for learning from each other increases when there are variations to consider, as opposed to the procedural approach of the first scenario.

Here is what group 2 noted:

What I learned	*2 brains better & quicker than one.* *Need to be organised; follow instructions carefully; more efficient to identify necessary pieces first.* *Need to think and decide what to do when part is missing.*
How I learned	*Following instructions to put pieces together in a particular way.* *Share thoughts, discussion and communicate; trial and error.*
How I felt	*Frustrated at times by unclear instructions & missing piece.* *Involved but would have liked better instructions; would have been easier with easier to follow diagrams.* *Part of a team.* *Pleased when it worked; sense of achievement; creating a finished product was fun.*

Scenario three opens up the potential to construct whatever is viable. Of course, the possibility of frustrating lack of progress is greatest in this situation but the opportunity for a heightened sense of satisfaction and boost to self-esteem is prodigious. What is built will arise from the child's imagination, drawing on any expertise already developed and may be undertaken just for the fun of it, or may surface from something of current interest. They may have a clear, specific picture of what should be the outcome or may only have a vague sense of intent. They may decide to plan and sort parts before starting construction or may choose to just get started and see what transpires. If a plan is created, the construction may go smoothly, especially as the child gains more experience. Also possible is that the plan does not work and modifications need to be made. This might be done by re-planning or by resorting to seeing what works. It may also be that, having planned, during construction an alternative occurs and modifications are made. In this context, the uniformity of the pieces may be a barrier to truly creative construction but will also act as security to build confidence. For the child who does not plan, the evolution of the model will be organic, progressing through trial and improvement. Either way, the eventual outcome may or may not be what they had in mind (if indeed this was ever clear). Also, they will likely have undergone a range of headways and regressions, frustrations and successes. If working with another child or children, the potential noted in the second scenario for gaining from each other (or for dispute) is magnified. They may well not be able to articulate what they have learned either in terms of knowledge of construction or in terms of persistence, determination, collaboration and so on, but they will be able to draw on their learning for the next time.

After the task, members of group 3 recorded:

What I learned	*Importance of friction/height/balance in this task.* *How parts work together.* *What did not work.*
How I learned	*Trial and error; improving on initial ideas; manipulating objects by using them for different purposes; looking at pieces to see how they connected.* *Building upon ideas of others; listening to & questioning others.* *Observation; thinking skills.*
How I felt	*Happy to achieve the goal; sense of achievement; felt that being in the group without instructions would be a good enough excuse if we didn't succeed!* *Fairly confident that the variety of pieces would eventually lead to success; wanted to find a simple mechanism for completing the task as quickly as possible; would like to try a better model, given more time.* *Frustrated; lack of patience to persist with something more complex.* *Would have chosen '1' but liked '3', having been made to do it.*

Most when asked said they would have chosen/preferred to be in group 1. Some would have preferred to work on their own, especially if doing the task in

group 3. No-one 'cheated' by looking at others' work. They were very much engaged with their own task. Other notes I took while observing were:

Group 1	*In seats. Knew what to do.* *Sorting pieces in accordance with instructions.* *1st to start building, & 2nd to finish (but much more complex model than gp 3).*
Group 2	*In seats. Least animated, most frustrated.* *Finding pieces against instructions (a piece missing).* *Modified (for missing piece).* *3rd to start & 3rd to finish.*
Group 3	*Out of seats. Talk most animated, freer, less constrained.* *No plans drawn/sketched.* *Looking at pieces and trying out to see what's possible.* *2nd to start/experiment & 1st to finish.* *Simple model & then thinking about improvements.*

When considering the connections of theory to practice, the students had some thoughts that related specifically to their experiences of the task on which they worked:

Group 1	*I could build confidently with the use of the instructions.* *Knowledge of bridges not needed when all instructions given.* *If the task doesn't require decision or creativity then you do not really think about it, just carry out a series of steps.*
Group 2	*We didn't all read the instructions in the same way or know how to solve the missing piece problem so some discussion helped to come to a consensus.*
Group 3	*The freedom that came with this task allowed for broader discussion while trialling different functions of parts and types of mechanisms we may be able to produce with the resources available.* *It also allowed creativity which would not have been present in other groups.*

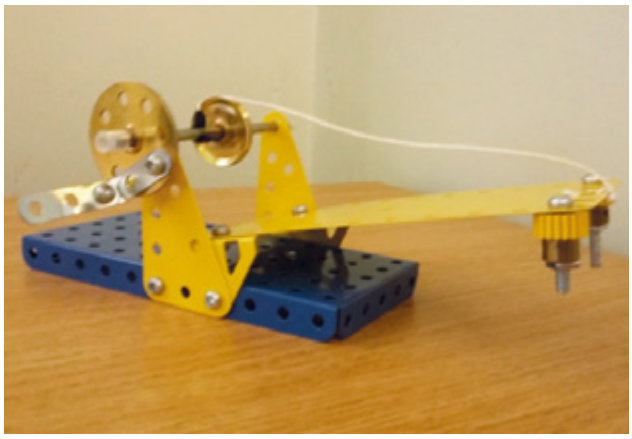
In addition to those above, there were many other comments that showed that they were drawing together the implications of the three scenarios for their practice in the classroom. In the table below, I have grouped these responses into three main areas: the differences between individuals; the role of working with others; and the agency gained from active engagement and challenge.

Differences	*Some people need more structure and others like a looser approach.* *Firm instructions suit some people but not all. People will start from different points.* *Everyone succeeded in the end but got there by different methods.* *One way does not suit all.* *People learn in different ways and have different experiences of modelling.*
Working with others	*Working as part of a team helps construct knowledge; thinking and doing in a social context; by working with others, people learn things they would not have been able to do alone.* *Tasks can seem daunting when facing them alone, working with others took off the pressure.* *Talk is important; sharing ideas in a safe environment.* *Perhaps some children gain confidence in their own ability purely from having the support of their peers, rather than their contribution to the task.*
Active engagement & challenge	*Learning is easier when you are at the centre of it, getting stuck in, learning by doing, trying things out, being part of a process.* *I don't like the idea of maths teaching being done to me.* *Using manipulatives to assist learning is important.* *Pupils learn through doing and experience.* *We should allow more independence & freedom in developing mathematical language.* *Handing over the decision making is more challenging than following instructions, therefore the learner is more deeply engaged and will learn more.* *Instructive/prescriptive learning has a potential limit which more creative, problem solving activities do not.*

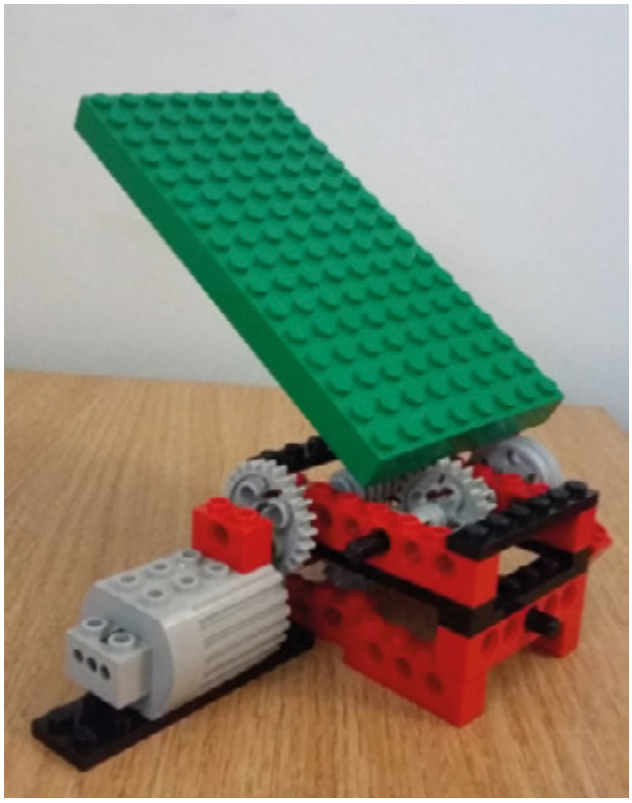
The student teachers' responses to the tasks and their analysis of what was being modelled illustrate the value of not only doing the tasks but also of the tutor modelling to the students the espoused principles of good practice. By undertaking the task, the student teachers were able to experience through active engagement how theory and practice are interwoven and hence will be able to extrapolate into the approaches we hope they will use for their teaching.

*Lego® also works.

Dr Judith McCullouch is a senior lecturer in mathematics education at the University of Winchester.



Sample of a Meccano® lifting bridge from scenario three.



Example of a Lego® lifting bridge from scenario one.

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