Connections, conjectures and problem solving in primary mathematics: The role of magic squares

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Recommended Citation
Chinnappan, Mohan: Connections, conjectures and problem solving in primary mathematics: The role of magic squares 2005, 33-34.
https://ro.uow.edu.au/edupapers/795

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Problem solving has been given focus in current reform statements and classroom practices of mathematics teaching and learning. Clearly, there is consensus on the value of engaging students in problem-based activities in which the learner will be driven to make more meaning from the apparent disparate concepts and procedures that are taught in the classroom. Research in the area of mathematical problem solving has identified numerous processes and knowledge components that support successful problem-solving attempts by young students. Among these, the need to model or represent a given problem appropriately has been the focus of debate in discussions about problem-solving activities in the classroom.

Broadly, activating previous knowledge and constructing new connections between prior understandings and information that appear in the problem context could facilitate modelling of a problem by young students. This involves a complex process during which students must reflect and explore various connections and decide which of these will lead to a solution or a series of solutions. The reflective and decision-making phase could in turn be supported by the quality of reasoning that students bring to the solution attempts. For this purpose, among others, mathematical reasoning has been acknowledged as a key component of the Working Mathematically strand in the NSW K–6 Syllabus. Chains of reasoning also constitute a key element in the development of algebraic thinking among young students.

Let us explore this strand further with a view to highlighting their role in the construction of the type of links that are necessary for students to make progress with mathematical problems. It would seem that the building of important connections could be achieved via a process of conjecture. In order to conjecture, students need to entertain the ‘what if’ question in their deliberations about the problem. That is, the consequences of taking a particular action need to be assessed and reassessed through argumentation and debate. Theories that promote the value of a sociocultural approach to understanding students’ approach to mathematical meaning-making acknowledge the role of conjectures and the ensuing dialogue among students working as a group in tackling problems.

The above analysis of the role of conjectures and connections in a problem context suggests that classroom practice could consider providing rich learning contexts that foster students’ independent exploration of problems. Specifically, problems that encourage students to draw on concepts from a range of previously learnt strands could be expected to catalyze the reasoning and conjecturing actions in meaningful and mathematically powerful ways.

Further such learning environments could act as a strategy for teachers to examine students’ understanding of mathematical concepts, procedures and conventions as well as providing opportunities for them to engage in activities that propel them to take a risk and debate potential actions and consequences of those actions.

In the following section I will attempt to demonstrate the use of one rich learning activity that satisfies the requirements that were outlined above. This focus activity involves students’ construction of and reflection on magic squares. What is a magic square? A number of teachers may have already been using this idea in their teaching. For those who are new to this, Figure 1 is an example of a $3 \times 3$ magic square that has nine cells or tiles. Students will recognize the spatial property in that the sides are equal in length. Each cell has a number from 1–9. However, the numbers, collectively, have interesting attributes, and it is these attributes that provide the magical aspect of the square in question here. That is, in Figure 1, the numbers in the cell satisfy the following relations:

$$a + b + c = N$$
$$d + e + f = N$$
$$g + h + i = N$$
$$a + d + g = N$$
$$b + e + h = N$$
$$c + f + i = N$$
$$a + e + i = N$$
$$c + e + g = N$$

The discovery of the above relationships among these numbers constitutes a key conjecturing activity, and could be provided as an initial activity for the students. The pattern to emerge from this exploration would be that the numbers when added horizontally, vertically or diagonally will provide the same number. Students could be provided with focus questions such as ‘find the pattern’, ‘what can you say about these numbers’, or ‘are these numbers related in any way.’ Alternatively, students could be asked to place the numbers in the cell such that the above relationship is satisfied. Conjecturing
could be enhanced by asking students who have found
the correct relationship to move the numbers from the
first row to the second/third row (or first column to
second/third column), and explain the result.

A further activity that could lead to creative thinking is to
see if the pattern holds for a $4 \times 4$ square with a different
set of whole numbers. The discovery of the history of
magic squares also constitutes a legitimate learning
activity that students would enjoy doing. The internet
could be an important source of information for the latter
activity, providing a rich context in which to generate
interesting and fun-filled but mathematically useful
discussions.

Providing grids on paper could support the above
conjecturing activities. Students could also be encouraged
to play with number cards or tiles that are arranged in the
form of a grid. The communication of the patterns
verbally or in written form by students is an integral part
of working with magic squares.