KITCHEN GARDENS

CONTEXTS FOR DEVELOPING PROPORTIONAL REASONING

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It is great to see how the sharing of ideas sparks new ideas. In 2011 Lyon and Bragg wrote an APMC article on the mathematics of kitchen gardens. In this article the authors show how the kitchen garden may be used as a starting point for proportional reasoning. The authors highlight different types of proportion problems and how the authentic context of a kitchen garden may be used to spark interest in reasoning.

Introduction

Across Australia, many schools have kitchen gardens. Some of these schools have been developed through the Stephanie Alexander Foundation while others, including the school described here, have chosen to create their own kitchen garden with the help of the school community. Lyon and Bragg (2011) described ways to integrate mathematics with other curriculum areas through the creation of a kitchen garden. This article focuses on activities used to engage students in a variety of mathematical situations involving proportional reasoning through a series of lessons in their school's kitchen garden. It also identifies the proportional reasoning problem types that arose through the activities.

Proportional reasoning is a key component of numeracy. It involves the ability to understand and use multiplicative relationships in situations of comparison (Behr, Harel, Post & Lesh, 1992). The importance of proportional reasoning in primary school children's mathematics education has long been recognised. Lesh, Post and Behr (1988) described it as the capstone of elementary school arithmetic and the cornerstone of the mathematics learning that follows. Being such a pivotal aspect of numeracy, the development of proportional reasoning skills is critical if children are to be well placed to succeed in mathematics beyond primary and indeed middle schooling. Failure to develop proportional reasoning ability by adolescence can also preclude students from participation in subjects beyond the middle years, including science, mathematics, and technology (Lanius & Williams, 2003).

Generally speaking, situations of proportion require some application of multiplicative or relative thinking. A variety of proportional reasoning problem types are identified in the literature. For example, Lamon (1993) identified the following types of proportion problems:

- *rate problems* (involving both commonly used rates, such as speed, and rate situations in which the relationship between quantities is defined within the question);
- *part–part–whole* (e.g., ratio problems in which two complementary parts are compared with each other or the whole); and
- *stretchers and shrinkers* (growth or scale problems).

In addition, according to Lesh et al. (1988), certain problem types are often neglected in textbooks and classroom instruction. These include problems that require transformation of representational types or modes. While providing students with opportunities to engage in a variety of proportional reasoning situations is important, it is equally important to expose students to situations that are non-proportional in nature (Bright, Joyner & Wallis, 2003) because students often rely on proportional reasoning in circumstances that do not require it — e.g., constant, linear and additive situations (Van Dooren, De Bock, Hessels, Janssens & Verschaffel, 2005).

Proportional reasoning is very often used in real-life mathematics; for example, comparing costs at the supermarket or estimating the travel time required to reach a destination on time. In schools, there exist many opportunities to develop students' proportional reasoning skills in authentic contexts. The focus of this article is the rich context of the kitchen garden.

Enhancing proportional reasoning in context

The authors are leading a project involving 28 schools in Queensland and South Australia. The project aims to enhance proportional reasoning education through a series of workshops with teachers within six school clusters over a period of two years. Each school cluster includes three to five primary schools with at least one of their local secondary schools. The research team works within clusters and individual schools to support teachers to develop activities that promote proportional reasoning across subject areas and within contexts relevant to each school or cluster. The schools in one of the participating clusters have a long history of collaboration and several of them have developed kitchen garden programs, either through the Stephanie Alexander Foundation or independently. Such programs involve students designing and planting gardens, growing and harvesting vegetables and herbs, and using their produce to create meals for themselves and their classmates, and, in some cases, the broader student community.

Lessons from one school

The research team were invited by one of the schools to work alongside their Year 5 teachers to develop resources and strategies for enhancing students' proportional reasoning through the school's kitchen garden program. In this school, students from each year level work on the project over the course of a school term during weekly 90-minute sessions (over approximately 10 weeks). Each week, one half of the students work on the garden (planting, soil testing, making compost, harvesting, etc.) while the other half of the students work in the kitchen (preparing, cooking and serving lunch). The groups alternate weekly so that over the term, all students will have spent about five sessions in the garden and five in the kitchen.

On the day that we observed the Year 5 kitchen garden class, the gardening students undertook activities that provided numerous opportunities for the teacher to engage the students in proportional reasoning and to foreground examples of proportional and non-proportional situations. These activities included investigating the components of soil samples and pH measurements. To investigate the different components in their soil samples, the students created water slurries in glass jars. This provided a range of proportional situations, including determining the relative amounts of the different components (part–part–whole comparisons) and comparing and identifying the various components according to their relative densities.

The students used pH kits with colour charts to determine the pH of soil samples. This allowed the teacher to draw the students' attention to an example of a non-proportional situation in which the scale appeared to be proportional and to help the students understand why this was not the case. (The pH scale is an example of a non-proportional scale; it is exponential — an increase of 1 on the scale represents a ten-fold decrease in acidity).

The kitchen is another rich source of opportunities to foreground proportional reasoning situations. On the day of our visit, the students were making potato marsala, breads and fruit kebabs. During preparation of the marsala, their discussions with the researchers centred around the size of potato pieces to ensure they cooked in the time available (a rate situation) and the ratio of different ingredients, depending on the number of people to be served (multiplicative thinking). The students were asked questions that involved manipulating the recipes, such as, "If I had three sweet potatoes instead of two, how many potatoes would I need to keep my vegetables in proportion?"

When making the bread dough, each student had to divide his or her dough into 15 pieces. This led the students to discuss the best shape into which to form their dough so that it could be easily divided into equal pieces. The students initially agreed that a circle would be best but once they started trying to break it into 15 pieces, it became evident that perhaps a different shape would be more useful because it was not an easy task. One student suggested a square and after a short time, the students decided as a group that a rectangle would be the best starting shape, as one student pointed out that 15 is not a square number. They then divided the rectangle into thirds, each of which they further divided into fifths. Figure 1 shows photographs of some of the students' 'dough shapes'. The photograph on the right illustrates the way in which the students divided the dough into 15 pieces.

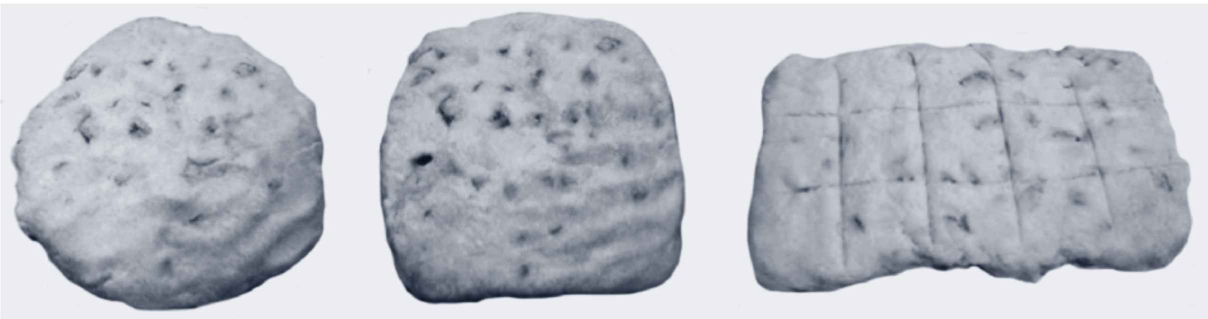

Figure 1. The dough shapes created by students.

This activity led to further discussions of situations in which a circle or a square might be a useful alternative to the rectangle. It provided the students with an opportunity to consider appropriate ways of representing parts and the whole (transforming representations). Such discussions are also valuable for promoting students' understanding of number. For example, the students soon realised that a square number would be most suited to a square shape whereas other numbers could be better represented as an array using the rectangular shape. In the case of the dough, the students created a 3 × 5 array. They agreed that the circle was difficult to divide into equal pieces, especially when the required number of pieces was odd.

The task of making fruit kebabs with a variety of five fruits provided opportunities to ask the students further questions about ratio. For example, one of the researchers asked the students to make the kebabs using a particular ratio of fruit: 1 : 2 : 1 : 2 : 1. The students each created a kebab in the required ratio without difficulty. However, when the ratio changed to $1 : \frac{1}{2} : 1 : \frac{1}{2} : 2$, and the students were challenged to create the kebab without cutting any pieces, the situation became more challenging. The students discussed the situation together before a student finally suggested, "doubling all the numbers will give us whole numbers". Once this idea was tabled, the students were able to create the desired kebabs. Again, this activity is an example of a simple situation in which the students were exposed to somewhat challenging ideas but through hands-on activity and group discussion, were able to reach a plausible solution to a part–part–whole problem.

While activities such as these may appear simple at first glance, they allow the students to engage in authentic problem-solving using a variety of ideas, including geometric shapes, arrays and number properties.

Case study teacher observations

At the beginning of the project, we met with the school principal, the Head of Curriculum, and the coordinating teacher of the kitchen garden. They asked us to develop a series of posters that could be used by the teachers while they were in the kitchen to draw students' attention to situations involving proportional reasoning and to prompt students' thinking. The posters were placed in the kitchen and have been used in mathematics lessons as a stimulus for students' problem solving discussions (see Appendix 1 for examples of the posters). The posters included prompts about the problem types, the types of thinking involved, and opportunities to use important terminology, such as 'relative', 'absolute', 'additive', and 'multiplicative'. This was done firstly to draw the students' attention to the types of thinking in which they were engaging and to encourage them to use the mathematical language. It also provided support for the teachers during their lessons.

After using the posters in class, the kitchen garden coordinating teacher reported in an interview that she had become more aware of the potential of the kitchen garden program for providing opportunities to engage the children in proportional reasoning. She stated that she was more likely to take the time to foreground proportional reasoning and to discuss it with the students. She also reported that in follow-up lessons in the classroom, she observed the students using proportional reasoning without being prompted to solve real problems as they arose in the garden. For example, the students were tasked with planning and building a new garden bed and needed to design an irrigation system. This became a rich numeracy activity, in which the students drew scale diagrams of the garden and superimposed diagrams to investigate the shapes and area of coverage for different garden sprinklers (two-dimensional scale). They also calculated and compared the flow rates from the tap to identify the most water-efficient sprinklers (unfamiliar rate problem). The teacher stated, "They were using proportional reasoning beyond their expected skill levels because they had a real reason for finding out the answers."

Future plans

In addition to the posters, other resources are being created to support the teachers and parent helpers in the kitchen garden program. Reflecting on the questions we had asked the students during our visit, one of the teachers noted that often teachers were so busy coordinating the students and ensuring that everything ran to time that they missed opportunities to engage the students in proportional thinking. In response, a series of question prompts to which the parents and teachers could refer during the kitchen garden sessions were devised. An example is shown in Appendix 2. It is envisaged that such resources will be devised to accompany each kitchen activity.

In most cases, one of the teachers makes the decisions regarding the amount of each ingredient that is required, based on the number of lunch orders received. There are plans in the future to engage the students more in these decisions, such as using the numbers of servings to determine the required multiple of each of the recipes, as well as assisting with decisions about quantities of ingredients to be ordered.

Benefits beyond kitchen garden programs

Not all schools have gardens or the resources to allow the students to carry out food preparation. The ideas described in this article grew from one school's kitchen garden project. Through sharing them with other teachers involved in the project, some teachers have been prompted to start a vegetable garden with their class. Teachers without such facilities have still found the activities and resources useful because they focus on authentic, everyday activities in which the students may engage in their lives beyond school. Teachers have used the posters in a variety of ways, sometimes as a stimulus for discussion, at other times, as a means of introducing a new topic or concept. Other teachers have used them for 'problem of the week' ideas. One teacher used the poster shown in Appendix 1 to introduce a mathematical investigation into scale factor and the effect on the volume of objects when one enlarges the shape in one, two or three dimensions.

When seeking to develop students' proportional reasoning skills, it is important to foreground situations of proportion and to engage students in proportional thinking in a variety of contexts. This article has described one approach to engaging students in such ideas through the context of kitchen gardens. The ideas started as a means of supporting the teachers in one school to engage students in a specific program. It has become clear to us that such ideas can be adapted and used effectively in a range of setting, across a number of year levels and for different purposes, thanks to the creativity and professionalism of the teachers involved.

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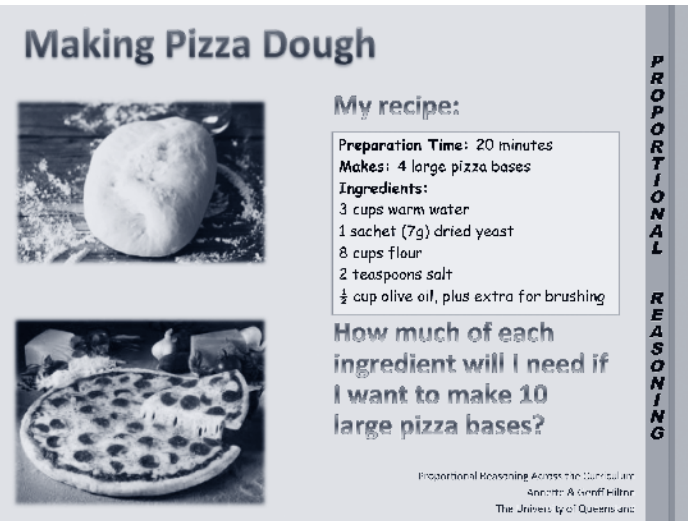
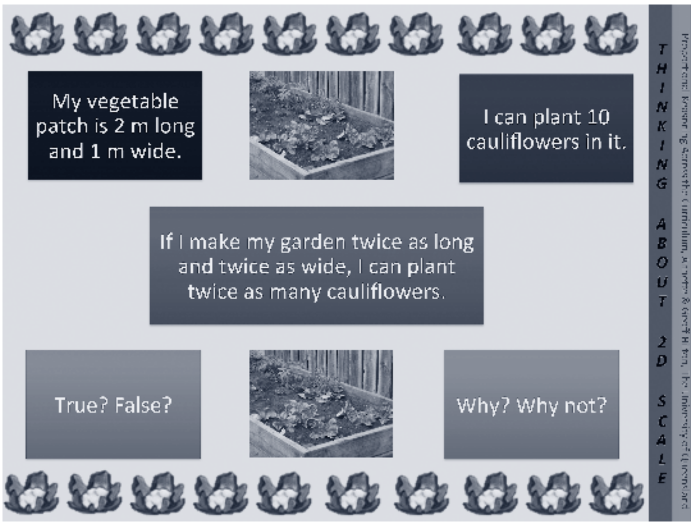
Appendix

Appendix 1. Examples of kitchen garden posters





Appendix 2. Guide for kitchen garden helpers

Sweet Potato Marsala

INGREDIENTS

8 tablespoons of oil
8 teaspoons of black mustard seeds
2 teaspoons of turmeric
8 cm piece of ginger: grated
2 onions
4 sweet potatoes
16 potatoes
spinach
4 cups of water to cook potatoes

Below are some possible questions to engage student proportional reasoning while preparing the recipe. This recipe example has numbers/amounts that are reasonably easy for students to manipulate, as they are all multiples of two. Many recipes may have numbers/amounts that will require thoughtful questioning to suit the mathematical understandings of the students. Also note that often a similar question can be asked in different ways.

1. *Additive/multiplicative:* If I made the recipe with three onions, to keep everything in proportion, how many sweet potatoes would I need?
    a. Possible responses: Some students may think additively, that is, they may think they have one more onion so they need one more sweet potato. We want them to think multiplicatively, that is, they have 50% more onions or half as many again so they need 50% more sweet potatoes, i.e., 6 sweet potatoes.
2. *Additive/multiplicative:* If I only had one onion, to keep the recipe in proportion, how many potatoes would I need?
    a. Possible response. This is similar to the first question but is a reduction. Again some students may think additively, i.e., reduce the onions by one and therefore the potatoes by one to a total of 15. Thinking multiplicatively, a student would note the number of onions have been reduced by 50% (or halved) so the potatoes would also need to be reduced by 50% (or halved) to 8 potatoes.
3. *Proportional/non-proportional:* Which ingredient listed is not strictly proportional to the other ingredients?
    a. The amount of water to cook the potatoes, while it could be varied with the number of potatoes to be cooked, does not need to be adjusted proportionally for success with the recipe.
    b. Spinach does not have an amount so must be added at the discretion of the chef/cook and therefore not strictly proportional.
4. *Proportions involving fractions:* If I only had 12 potatoes, to keep the recipe in proportion, how many onions would I need?
    a. This is a more difficult question as it involves the students' fractional thinking. Twelve potatoes are $\frac{3}{4}$ (or 75%) of sixteen potatoes so the recipe would need $\frac{3}{4}$ (or 75%) of two onions, i.e., $1\frac{1}{2}$ onions.
    b. This question can cause confusion with children who are additive thinkers. They may think they have four fewer potatoes and need four fewer onions but only have two. This could be a good way of demonstrating that when thinking proportionally, additive thinking does not work.