

2024 Premier’s University of Sydney Mathematics Scholarship

Naturally Mathematical

How school gardens provide fertile grounds for growing young mathematicians

Jessica Francis

West Ryde Public School

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# Introduction

My observations as a teacher for over 20 years, and my scholarship research within Australia and across Denmark and the UK, show that regular gardening lessons promote students’ Functional Use of Number (FUN) and Positive Learning Dispositions (PLD). During my research, many discussions centred on assessment and “covering the content”, with teachers in NSW and internationally feeling compelled to prioritise speed of knowledge transmission over depth of understanding. My study finds that this approach is inefficient, and it is more effective to regularly contextualise mathematics content through authentic activities such as a gardening program.

Throughout my study tour I tested the relevance and rigour of *The Sunflower System*, a planning tool I have developed to be compatible with the *NSW Department of Education (DoE) units of work* or any other maths program used in schools. *The Sunflower System* identifies essential elements of explicit teaching and is flexible enough to be used in each unique school context.



Figure 1: The Sunflower System planning tool (Canva design by Jessica Francis, 2024)

# Focus of Study

Emeritus Professor Peter Sullivan and 2019 Premier’s Teacher Scholarship (Mathematics) recipient Kirsty Thorpe identified that FUN, PLD and creativity are vital to students successfully solving mathematical problems. I was keen to find an answer to the question of “What would mathematics teaching and learning with [Sullivan’s] six key pedagogical principles look and sound like?” The study tour included visits to schools and businesses with gardens, museum tours and conferences. A wealth of international research shows that regularly spending time in nature improves wellbeing for people of all ages, therefore my research extended to forest schools, outdoor schooling and sites such as Kew Gardens and The Eden Project.

The purpose of my study tour was to research the following question:

* Can a student-centred nature education pedagogy be compatible with the highly structured and sequenced approach recommended by mathematics experts?

# Significant Learning

Throughout the study tour some of my earliest hypotheses were affirmed, and my horizons were opened as to what is possible when using gardening to contextualise mathematical skills. I was also confronted with the reality of challenges that must be overcome both in terms of maintaining a school garden and in teaching mathematics. I discovered that school gardens come in all shapes and sizes and are limited only by the resources available within the community or through various grants. The gardens I visited ranged from permaculture food forests to container gardens, a strip of soil at the back of a school in the countryside to a wild garden nestled in the heart of a mega-city, an indoor rainforest and a school that is outdoors all year round. School gardens can be onsite or maintained by local churches, charities and councils.

In my own teaching practise, I successfully use gardening to reinforce and contextualise the mathematical skills and concepts that are introduced in the traditional primary school classroom setting. The research tour gave me the precious opportunity to observe gardening teachers and forest school educators, and to objectively analyse the mathematical skills and language that are naturally used as part of the authentic activity. I have learned strategies for communicating the success of gardening programs to others, and analysed how success is measured.

I attended mathematics conferences and conducted interviews with staff at schools and education departments about the practises they use and the barriers we all face. My research reinforces the claim that there are many benefits to using gardening as a mathematical pedagogy.

The themes explored in this report are:

* Providing a context for growing mathematical problem solvers
* Gardening embodies Sullivan’s six key pedagogical principles
* Fertile ground for growing mathematical mindsets
* Measurement matters: Highways and deep ways in a fast knowledge environment

### Providing a context for growing mathematical problem solvers

I was fascinated to learn about outdoor education sessions that take a much more student-centred approach than those that aim to “cover the content” of the syllabus. Mathematics, gardening and forest school educators I spoke with report that students develop a sense of connection to the garden or forest school space when they have responsibility for caring for it. They understand that problem solving does not take place over the course of an hour but can take several weeks or even beyond one’s own lifetime. I observed teachers supporting students to use trial and error to solve practical problems that naturally arose throughout the gardening or forest school session, and students suggesting activities which can provide problems to solve in future lessons. Teachers found this approach empowering because planning is responsive to the needs of their students.

In his keynote address to the MANSW K-8 Conference *Playing with pedagogy*, Prof. Matt Sexton urged teachers to be less bound by what we feel we should be “covering” and more inspired by how we could be teaching our students to think. My research supports his position that teaching decisions must be made intentionally with the impact in mind. To describe gardening as a student-centred pedagogy does not exclude opportunities for intentional use of language, addressing mathematical misconceptions or fluent and functional use of number. Prof. Sexton critiqued a dependence on the *I Do, We Do, You Do* framework. He suggested that a lesson could follow a *You Do, We Do, You Do Some More, We Summarise Together* model, though even this would be flexible and responsive in the moment. Once the routines and norms of a gardening session have been established, students are empowered to explore their curiosity and launch into the *You Do* phase almost immediately at the beginning of a lesson.

The need for a child centred mathematical pedagogy was reinforced during Dr Danielle Armour’s keynote address at the MANSW Annual Conference in which she spoke about *Co-constructing indigenous perspectives and knowledges in STEM*. My *Naturally Mathematical* approach to planning lessons using the *Sunflower System* is compatible with the principles and phases of co-constructing which Armour identified and provides “direct experience in the environment”. A school garden is a perfect opportunity for growing reciprocal relationships when communities and schools work in long-term mutually beneficial, organic partnership with each other.

### Gardening embodies Sullivan’s six key pedagogical principles

The student-centred gardening and forest school sessions I observed provided many opportunities to demonstrate Sullivan’s six key pedagogical principles as detailed on [Mathematics Hub](https://www.mathematicshub.edu.au/plan-teach-and-assess/teaching/teaching-strategies/). To maximise the potential of this approach for teaching the curriculum, students should be supported to articulate and evaluate the mathematical goals of the session. Regular *Naturally Mathematical* sessions enable teachers to consistently establish the expectation that students and teachers will apply the focus skills and communicate through the key mathematical vocabulary which has been taught in the classroom.

Gardening sessions demonstrate Sullivan’s principle of making connections because students are given a context for applying the often disembodied, abstract concepts they are taught in mathematics lessons. [Mathematics Hub](https://www.mathematicshub.edu.au/plan-teach-and-assess/teaching/teaching-strategies/) explores this principle further by encouraging mathematics teachers to make cultural connections to the concepts and skills they are teaching. During my study tour I saw examples of gardening as a culturally conscious practise as staff at Gørding Skole, Queen’s Park Primary School and Guildford High School educate themselves and the students about plants that are indigenous to the area and the way humans interact with local ecosystems. I was surprised at how often the guidance of *Pædagogisk Praktisk Permakultur* authors Holmstrup & Lykou (2022) was similar to Sullivan’s principles. For example, each recommend that students learn about the cycles of nature, and the opportunity to participate in gardening at various times of the year and over the course of several years will provide that experiential learning. Interviews with mathematics teachers at Gørding Skole, The Eden Project and Guildford High School reinforced my hypothesis that the mathematical potential of gardening lessons can be enhanced by the intentional use of mathematical language to discuss students’ observations and record their findings.

Fostering engagement through a student-centred approach is not only essential for empowering students to develop responsibility but is also crucial to using gardening as a problem-solving activity in primary schools. I discovered that each school garden or outdoor education facility is as unique as the community in which it is set. This significantly influences the design of gardening lessons. The approaches taken by schools and education departments can be broadly categorised as student centred or knowledge transfer based. Those using the knowledge transfer approach experienced difficulty finding ways to occupy the students each week and throughout the entire session because activities relied on following the instructions of teachers and volunteers rather than students exploring nature and posing solutions to problems they self-identified. Schools and education departments that “dare to take the children seriously” (Holmstrup & Lykou, 2022) overcame this challenge by not only allowing students to participate but to also take a lead role in the direction of the gardening program, recognising that “each student brings to the classroom a unique background as an individual learner” (Mathematics Hub n.d.).

In a knowledge-transfer based approach to planning problem-solving lessons, differentiation occurs by extending and scaffolding a selected activity. According to Mathematics Hub (n.d.) this is “one of the hardest” challenges that teachers face. However, many young mathematicians require more contextualising experiences to grow their understanding before these often representational or abstract tasks have meaning for them. In the most successful gardening and forest school sessions I observed, the tasks were differentiated by giving students the opportunity to select from a range of familiar activities or those that had been requested by the children themselves. Students had the freedom to move between activities as they chose and to work in flexible groups of their own design. The role of the teacher in a *Naturally Mathematical* session is not to feel overwhelmed by the process of finding and modifying each activity to three levels of difficulty so much as it is to intentionally prompt students to reflect on their application of mathematical skills, understanding of concepts and use of the language that was introduced in the classroom. This approach embodies Schoenfeld’s research into prompting for problem solving which was widely promoted at the MANSW Annual Conference. It supports students’ move from a reliance on concrete manipulatives to connecting with representations and abstract concepts.

Gardening programs can promote fluency and transfer through pedagogical decisions which involve spaced, interleaved and retrieval practice of applying the mathematical language, skills and concepts. The observations of my study tour indicate that authentic gardening or forest school sessions do naturally contain implicit opportunities for such practice, however the potential of these activities must be made explicit through intentional decision making. *The Sunflower System* planning tool provides a simple structure for informing these decisions. Teachers must develop a routine which clearly establishes the expectation that the abstracted language and skills of the classroom will be used in the direct experience of learning in the garden. The garden can be seen as a dynamic context for challenging mathematical concepts, thereby allowing students to develop responsibility for their own learning as well as for the plot and plants in their care.

### Fertile ground for growing mathematical mindsets

Jo Boaler and her colleagues (2021 and n.d.) have identified positive dispositions for developing a mathematical mindset, which are skills for working mathematically. The dispositions include:

* the ability to solve problems as part of a group,
* an interest in discussing the process of working out and thinking, rather than focusing only on the answer,
* mathematicians feeling comfortable with "struggle” and developing perseverance,
* students and teachers valuing the depth of learning as well as the speed of answering questions.

Gardens as a context for mathematical problems provide the opportunity to reset expectations that can be difficult to overcome in the classroom. Mathematics is often perceived as something an individual is “good” at based on their quick recall of number facts. In gardening sessions I have taught, young mathematicians were invited to demonstrate their expertise through solving authentic problems such as calculating how many seeds or seedlings can be sown in each bed or will there be enough of a particular crop to feed the entire grade or only one class. In terms of differentiation, these questions may seem simple to answer using the *I Do, We Do, You Do* model. However, it is through opportunities for students to pose their own questions and direct their own inquiries that a gardening program is an effective example of universal design for learning.

Intentional decisions in the garden can support concrete thinkers who struggle to record abstract ideas, and challenge abstract thinkers who have an unstable foundation in concrete modelling despite their ability recall answers quickly. At Gørding Skole, students measured the growth of their bean sprouts weekly. This activity develops functional use of number by reinforcing the students’ discrete ability to measure in millimetres, and through comparing lengths to find the difference each week. Students spontaneously asked their peers mathematical questions based on this simple, familiar problem and were supported to record their findings using increasingly formal methods and symbols. The Mathematics exhibition at London’s Science Museum illustrates that this discipline depends on more than factual recall, highlighting the importance of questioning how patterns and formulas can be used solve complex problems in dynamic environments.

### Measurement matters: Highways and deep ways in a fast knowledge environment

If we are to make room for gardening as a mathematical pedagogy, we must address the concept of time. Teachers who have not experienced the benefits of regular gardening or forest school sessions tend to believe they must find time “on top of” all the other competing demands for their planning and teaching time. Though many of the schools I visited do not explicitly use this time to teach or support mathematical learning, they consistently report that students are noticeably calmer, able to self-regulate and are more engaged in class-based learning when they participate in gardening or forest school sessions that last from one hour to a full school day each week.

The findings of my study tour are consistent with those of Thorpe (2019) who identified that pressure to perform in standardised assessments can negatively impact the quality of teaching in a classroom. This mindset has been referred to as the “Olympics of learning” (Clark, 2023) where teachers become overwhelmed by the expectation that once a goal has been achieved, they must surpass it with the next class, regardless of the students’ starting point. The message may be *faster, higher, stronger* but this pressure can potentially leave teachers feeling undervalued and overworked.

# Conclusion

My research shows that gardens can provide fertile grounds for developing FUN and PLD and has deepened my understanding of the current research on improving mathematics teaching. I have gathered examples of how gardening programs can provide a structured environment for rich mathematical discussions and the type of ‘low floor, high ceiling’ tasks that Thorpe, Boaler and Sullivan found are vital for creativity in mathematics. Nature education is an evidence-based practise and not an additional demand on top of an already crowded curriculum.

Example lessons for using the Sunflower System planning tool and a suggested K-6 scope and sequence for gardening are available on my blog ([Naturally Mathematical](https://naturallymathematical.wordpress.com/)). The system is designed to support the DoE units of work, or any other scope and sequence used by a school. My research has been extensively shared via the [Naturally Mathematical Facebook group](https://www.facebook.com/groups/296695289380033) and [blog](https://naturallymathematical.wordpress.com/), and online and in person though a wide variety of professional networks.

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7. Spitalfields City Farm, London
8. Kew Gardens, London
9. Queen’s Park Primary School, London
10. Wiltshire Wildlife Trust and Fitzmaurice Primary School, Bradford-on-Avon, UK
11. The Eden Project, Cornwall, UK
12. Guildford High School, Guildford UK
13. MANSW Annual Conference, 2024,*Teaching for, about and through problem solving*

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