Improving Computational Thinking with Spatial Skills Development in Primary School

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ABSTRACT

Spatial skills frequently correlate with many measures of computing success, and indeed with wider STEM achievement. Spatial skills training has also been shown to improve computing outcomes at multiple institutions of higher education with first-year university students. However, there is a good chance that even though we can improve the spatial skills of undergraduate students to help them succeed at computing, many students will have already opted-out of computing learning pathways in school due to poor spatial skills. Using a spatialised maths curriculum, we intend to improve the spatial skills of primary school children aged 8–9 and investigate the effect on their computational thinking. With this poster, we would like to share our work so that others can consider deploying similar programmes, and to hear feedback from the CS education community on what other aspects and factors we should consider.

CCS CONCEPTS

• **Social and professional topics** → **K-12 education**; **Computational thinking**.

KEYWORDS

spatial skills, computational thinking

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1 INTRODUCTION & BACKGROUND

Spatial skills are cognitive skills involving understanding and conceptualising space and spatial concepts, particularly internally. Mental rotation (being able to predict a 2D or 3D shape in an alternative orientation), mental transformation (being able to mentally "fold up" a 2D flat pattern into a 3D object) and spatial orientation (understanding the relationships between objects around a point) are examples of spatial skills. Parkinson & Cutts give summarise several factors of spatial skills in relation to computing science (CS) [10].

Spatial skills have been associated with STEM success for decades [15], and with CS success more recently [1, 3, 5, 10, 12]. The relationship appears to exist at all levels: spatial skills can predict maths success at a very young age [17], and are associated with success in CS Masters degrees [5]. Spatial skills also appear to have a lasting predictive effect. In 1960, 440,00 high-school students in the USA took a spatial skills test as part of a wider battery of tests. Wai *et al.* identified that of those later achieving STEM PhDs, 90% scored over 70% in the spatial skills test [18]. Similarly, Parkinson & Cutts identified that a spatial skills test taken in first year of university CS accounted for 38% of the variance in final graduating GPA [12].

Spatial skills are malleable [16], and several studies have shown that improving spatial skills can lead to improvements in CS assessment [1, 3, 11]. However, most studies in CS to date have been at a university level, when pupils with low spatial skills have probably already dropped out of routes to CS due to poor spatial skills. In the general population the people with the lowest spatial skills are typically women [6] and people from low-income backgrounds [4], so fixing these routes should be a priority.

It is hypothesised that gaps in spatial skills in the general population are caused by play experiences. Some toys, games and play experiences develop spatial skills, such as construction toys or block play [2] and video games [19]. While, of course, childhood experiences are never totally homogeneous amongst demographic groups, such experiences are typically presented to boys and can be prohibitively expensive, explaining the gap in spatial skills which opens early and remains until higher education [4].

In order to ensure that every child develops spatial skills, spatial skills development should be built into the school curriculum. We should not assume that pupils will have the opportunity to develop spatial skills in their own time through extracurricular experiences, and rather should ensure that typical routes through school should develop the skills required for later success.

2 THE PROJECT

2.1 Spatial Skills Development

We have launched a project to examine the effect of developing spatial skills for school pupils aged 8–9. The spatial skills development vehicle is a partial maths curriculum developed in Australia called MathsBURST[1]. It teaches some aspects of the Australian maths curriculum for Years 3–6 (ages 8–12) using spatialised methods. This consists of deliberate use of activities involving concrete manipulatives and a gradual progression to abstract, mental tasks.

MathsBURST has successfully improved both spatial and maths outcomes for enrolled pupils [7–9]. However, MathsBURST has

[1] https://mathsburstprogram.com.au/

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only ever been used in Australian schools and has only ever been used to examine improvements in maths and spatial skills outcomes. Our project brings MathsBURST to the UK and will additionally explore the curriculum's effect on computational thinking.

2.2 Pre- and Post-tests

We will conduct pre- and post-testing using age-appropriate tests in three areas:

- Spatial skills, using the Spatial Reasoning Instrument (SRI) developed and validated for ages 8–9 by Ramful *et al.* [13].
- Mathematics, using a test developed from items in the Australian National Assessment Program (NAPLAN) Numeracy test, developed by Lowrie *et al.*, which was closely analysed to also align with typical UK curriculum benchmarks of mathematics for the same age group [9].
- Computational Thinking, using the TECH2 version of the TechCheck test, a validated Computational Thinking test for the age group in question [14].

While the curriculum has been shown to improve maths and spatial skills outcomes already (albeit in a different context), computational thinking is an entirely new measure.

2.3 Delivery Overview

For the UK pilot of the MathsBURST curriculum, we will be focusing only on the earliest year group covered by the curriculum: ages 8–9. We have around 20 experimental schools involved delivering training and 10 control schools who will only conduct testing.

Prior to the submission of this poster, we conducted focus groups with teachers who would be involved in the delivery of the materials. These focus groups helped us to identify opportunities and challenges with the existing materials and our proposed delivery plan (e.g., noting that some elements of the lesson plans would not work so well in typical UK classrooms and making sure we were aware of resources teachers are likely to have access to).

The curriculum will be delivered August–December 2023, with the pre- and post-tests taking place in the first and last weeks of term. During teaching, we will be collecting weekly reflections from the involved teachers and observing classroom activities. We will also be conducting additional observation of STEM activities after training has been completed in both experimental and control group classrooms in January–March 2024, to determine if the effects of the curriculum can be observed in typical classroom activities.

3 CONCLUSION

The purpose of this poster is to spread awareness of our project and to seek guidance from the international CS education community concerning engaging with children aged 8–9. We want people to know about the work we are doing involving developing spatial skills to improve CS outcomes for younger groups of children than have previously been examined. We are particularly interested in knowing what other aspects of childhood development we should be considering with respect to computational thinking. We also hope that by sharing our work, we can encourage others to explore the possibility of spatial skills development for primary school pupils in order to improve their chances in later school, particularly in CS and in their STEM subjects in general.

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