PROJECT TITLE	**Pilot Evaluation of SPAtial Cognition to Enhance mathematical learning**
DEVELOPER (INSTITUTION)	University of Surrey
EVALUATOR (INSTITUTION)	Centre for Evidence and Implementation
PRINCIPAL INVESTIGATOR(S)	Jane Lewis
EVALUATION PLAN AUTHOR(S)	Amy Hall, Jane Lewis
PUPIL AGE RANGE AND KEY STAGE	Year 2 (6- to 7-years old, KS1)
NUMBER OF SCHOOLS/ SETTINGS	15
NUMBER OF PUPILS	Approx. 450

Evaluation plan version history

VERSION	DATE	REASON FOR REVISION
1.0 [original]		[leave blank for the original version]
2.0	10/11/2023	• Minor change in teacher survey procedure, inclusion of teacher survey in appendix B. • Minor change in research question wording. • Minor amendment to assessment observation plans. • Added detail on incentives. • Added a new member on the evaluation team

Intervention overview

Background

Many adults experience difficulties with mathematics, and low numeracy is consistently found to have negative social and economic consequences for both the individual and society (Gross, Hudson, & Price, 2009; Ritchie & Bates, 2013). The development of early mathematics knowledge is critical to later mathematical skills (Dowker, 2005) and children from disadvantaged families start to fall behind from an early age, indicating the importance of early interventions to prevent or ameliorate such difficulties (Janus & Duku, 2007).

Despite its importance to children developing an understanding of the world around them, spatial reasoning is often overlooked by policy makers (Moss et al., 2016). Indeed, in 2018 shape and measurement were removed as learning goals from the Early Years Foundation Stage statutory framework for children in England. These goals have not been reintroduced, despite the government acknowledging their importance to children's mathematical development in 2020 (Gibbons, 2020). Furthermore, spatial thinking is not included in the Key Stage 1 "Ready to Progress" criteria produced by the Department for Education. Early years and mathematics specialists argue that more focus on spatial reasoning in the early years and primary curriculum would benefit all children, and particularly those from lower SES families (Bower et al., 2020; Gifford, 2019; Gilligan-Lee et al., 2022).

Spatial ability involves being aware of the location and dimension of objects and their relationships to one another and is an important part of children's maths development. Gilligan-Lee et al. (2021) found that spatial language predicts several components of spatial skills, including scaling and perspective taking. Furthermore, spatial language accounted for variance in standardised mathematics outcomes, even when spatial skills and receptive vocabulary skills were controlled for, demonstrating that it has clear implications for success across the curriculum. Teachers' use of spatial language in the classroom is therefore a crucial component of any intervention which aims to improve spatial skills.

Recent evidence suggests a relationship (medium to large effect size) between spatial ability, especially spatial working memory, and arithmetic (Allen & Dowker, 2022; Cornu et al., 2018; Mix et al., 2021) and that early spatial skills may predict later maths skills (Gilligan et al., 2018). Furthermore, spatial training may improve children's early maths skills (Bower et al., 2020) and there is evidence for a causal relationship between spatial training using physical manipulatives and mathematical development (Hawes, Gilligan-Lee, & Mix, 2022). This highlights the potential importance of interventions to promote the development of spatial abilities.

There have been relatively few studies on the impact of spatial training on long-term mathematics outcomes so far. However, compared to studies of some other types of intervention (Dowker, 2017), those undertaken have given promising results (Cornu et al., 2017; Hawes, Gilligan-Lee, & Mix, 2022; Lowrie, Logan, & Ramful, 2017), particularly for children from disadvantaged families (Bower et al., 2020; Schmitt et al., 2018; Verdine et al., 2014) highlighting the potential role of these approaches in narrowing the mathematics attainment gap.

The intervention

SPAtial Cognition to Enhance mathematical learning (SPACE) is a whole-class structured approach to Lego® play which aims to improve 6-7-year-old (Year 2) children's spatial

thinking and mathematics outcomes, developed by the University of Surrey. The theory of change diagram is attached as an appendix.

In this pilot trial, teachers and teaching assistants in 15 schools will be trained to deliver SPACE, with teachers leading and teaching assistants supporting delivery in each school. Staff training be delivered by the University of Surrey delivery team and will consist of a half-day training session. To maximise implementation effectiveness, the delivery team will also provide support materials and fortnightly support. Teachers will also be given resources to help them encourage children's spatial thinking and spatial language during SPACE sessions. This includes spatial thinking prompt cards and a comprehensive delivery manual.

Each class taking part in the evaluation will be provided with Lego® packs suitable to make all required models for each child. Teaching staff will be provided with weekly themed 2-minute videos which they can use to introduce the 'story' of the sessions in that week.

The SPACE programme is delivered during maths lessons by teachers and teaching assistants in two weekly 30-minute sessions over six weeks (12 sessions total). SPACE sessions follow a common format. Each session will begin with the teacher or teaching assistant presenting the 'story' for the session, and presentation of the 2-minute video. For the main activity, each child is given an instruction booklet to follow which includes exploded Lego® models of familiar objects (such as a crown or a tree) which children then build using Lego® bricks. Children will be able to build up to six Lego® models per session. In the sessions, children are intended to work largely autonomously and self-paced, with each child working on their own models. Teachers and teaching assistants provide support via spoken prompts, to encourage children to use spatial thinking to problem solve and to expose children to spatial language.

The 'model booklet' given to each child includes the pictorial exploded models to follow as well as a tick box page for children to tick the models they have completed. The tick boxes are intended to act both as motivation and a way of monitoring task completion, though children will not be required to complete all models.

Sessions will take place in normal school classrooms, within the regular mathematics timetable. SPACE has been designed to complement and support the mathematics curriculum in the following areas: Geometry - properties of shapes, Geometry - position and direction, Measurement, Fractions, Place value, Multiplication, Addition and Subtraction.

SPACE is primarily designed to be child-led and self-paced, meaning teachers and teaching assistants can use their judgement on when to provide support. Delivery with fidelity means that teachers do not physically manipulate the Lego® bricks themselves but encourage children to problem solve using spatial thinking and spatial language. The use of these techniques is given more importance than the number of models completed by each child.

The evaluation

This pilot evaluation will assess the feasibility of implementing SPACE, identify evidence of promise, and establish the readiness of SPACE to be delivered at scale. It will involve:

- observation of training and delivery sessions
- online survey of trained teaching staff at three timepoints
- interviews with the delivery team, teaching staff, and senior leadership representatives
- piloting an assessment of children's spatial and mathematics ability, before and after receiving SPACE.

Schools will be offered a £500 incentive at the end of the project, £250 for completion of pre-intervention assessments and £250 for completion of post-intervention assessments, to ensure the child assessments did not act as a disproportionate disincentive to taking part.

Research questions

The evaluation will focus on three areas: feasibility of implementation, evidence of promise, and readiness for an efficacy trial.

Feasibility of Implementation

1. **Is SPACE feasible for implementation in maths lessons?**
   This will include considering the necessarily conditions or facilitators (school- and teacher-level) for SPACE to be implementable in schools.
2. **Are the training and support provided sufficient for teachers and teaching assistants to implement it?**
   This will include the initial training and support sessions as well as the resources providing, including attendance at sessions and any barriers to accessing support.
3. **Was it implemented as intended?**
   Here we will assess whether fidelity criteria for delivery were met, and facilitators and barriers to this.
4. **Is it acceptable to teaching staff?**
   This will include teaching staff's views about SPACE and whether they would want to deliver it outside the study context
5. **Do children, particularly those from disadvantaged backgrounds, engage well with it?**
   This will be based on teachers' assessment of children's responses to SPACE sessions, with some indicative data from our observation of SPACE sessions.

Evidence of promise

6. **Do the training and delivery of SPACE sessions lead to changes in teaching staff's understanding of the importance of spatial skills, use of spatial language and confidence in teaching spatial skills?**
   These are key areas for change identified in the theory of change.
7. **What impacts do teaching staff perceive for children, particularly for those from disadvantaged backgrounds (e.g., spatial language, spatial skills and mathematics skills and attainment)?**
   This will be based on teachers' perceptions of how children's aptitude has changed.
8. **What are the perceived mechanisms and possible causal chains?**
   Here we will explore teachers' perceptions, including (but not limited to) assessing mechanisms identified in the theory of change.

Readiness for Trial

9. **How could SPACE be delivered on a larger scale?**
   This will include the SPACE team's plans and ambitions for scaling, whether and how the SPACE team could provide training and support to schools at greater scale, and options for increasing team capacity.
10. **Are the proposed whole-class assessment measures appropriate for use in an efficacy trial?**

Here we will explore whether they can be completed as required in either one or two sessions, and teachers' views on its acceptability to them and to children.

Table 1. Success indicators and assessment methods

Pilot criteria	Success Indicators	How to assess this?
Feasibility of implementation	F1. Teaching staff consider the intervention implementable (with minor amendments)	Teaching staff surveys, teaching staff interviews, observations
	F2. Teaching staff consider the intervention acceptable (with minor amendments)	Teaching staff surveys, teaching staff interviews, observations
	F3. Schools are able to deliver the intended intervention dosage within the defined period[1]	Programme monitoring data, teaching staff interviews
	F4. Schools are able to deliver the intervention with medium to high fidelity[2]	Teaching staff surveys, teaching staff interviews, programme monitoring data, observations
Evidence of promise	P1. Findings indicate that SPACE has a positive influence on teacher knowledge, understanding and/or confidence in spatial skills	Teaching staff surveys, teaching staff interviews
	P2. Indication of SPACE leading to improvements in children's spatial reasoning and mathematics skills	Teaching staff surveys, teaching staff interviews, child outcome measures
	P3. There are no indications that pupils receiving free school meals benefit less from SPACE, or that there are barriers to some pupils benefiting from SPACE	Teaching staff and SLT interviews
Readiness for scale	S1. There are viable strategies to collect sufficient data to monitor compliance and fidelity	Programme monitoring data, delivery team focus groups
	S2. SPACE can be scaled for an efficacy trial (with minor amendments)	Observations, teaching staff and SLT interviews
	S3. There is a viable vision for delivering SPACE at scale	Delivery team focus groups, SLT interviews

[1] The programme is designed to be delivered as 12 30-minute sessions delivered over six weeks with a maximum of two sessions per week. To account for school term times, staff illness and other unforeseeable interruptions, 'intended dosage' allows for delivery of the 12 sessions over eight weeks with a maximum of three sessions per week.

[2] Fidelity will be established using a composite score which incorporates key elements of programme fidelity, including dosage, training attendance, and delivery quality.

Methods

Recruitment

Fifteen schools will be recruited for the project (plus three schools on the waiting list in case any drop outs), each enrolling one class (approx. 30 children) selected by the school in the programme. To be eligible, schools must be mainstream state-funded primary schools in England with at least one Year 2 class, and they must not already be delivering a maths intervention in Year 2. Schools will be recruited from pre-defined geographical areas, namely Portsmouth, Surrey, Hampshire plus Swindon in the case that we do not recruit enough schools from Portsmouth. At least half of the schools that participate will be recruited from education improvement areas.

This sample size is considered sufficient at this stage of evaluation, to understand the implementation determinants of SPACE and the feasibility of outcomes data collection across a spread of school sizes, types, and locations.

Recruitment will be led by the delivery team at the University of Surrey via the EEF website, where schools can find projects that they are eligible for and register their interest. They will also use emails and phone calls to their existing networks of schools and contacts (e.g., via Learnus and maths hubs), as well as schools identified through their websites. There are three stages of recruitment: 1) approval will be sought from the schools' Headteacher, 2) teaching staff of the chosen class will receive an information sheet and consent form via the Headteacher and provide their consent, 3) all parents/guardians of children in the chosen class will be informed of the programme using an information sheet sent and given the option to withdraw their child from the evaluation. Headteacher approval (with the option for parents to opt their child out) is considered appropriate for this evaluation because SPACE will take place during regular maths lessons and the content falls within the range of usual curriculum activities.

Measures

Teaching staff measures

The teaching staff survey will be developed to assess self-reported changes in teaching staff's confidence in and understanding of using spatial skills in the classroom, the feasibility, acceptability and appropriateness of SPACE, perceived impacts of SPACE for children, and the continued use of spatial skills beyond the intervention. These measures will provide insights into the areas of teaching that delivering SPACE influences.

Measures of staff confidence and understanding

The items relating to spatial skills will be based on existing measures of teacher beliefs and behaviour, such as Bates et al. (2023), and Gilmore & Cragg (2014), and adapted to be appropriate for this study

Measures of perceived impact

CEI will develop items to explore teachers' perspectives on the impact of SPACE on children's numeracy and spatial skills based on previously used and validated measures.

Measure of implementation

Implementation effectiveness (based on the dimensions of feasibility, acceptability, and appropriateness) will be assessed using the Weiner implementation outcome measures (Weiner et al., 2017); a well validated scale designed for intervention evaluations. Additional

questions about specific elements of the implementation strategy will be developed by the evaluation team.

Child assessment measures

The child assessment measures will be developed by the University of Surrey delivery team as part of their EEF grant, with review by the maths expert from the evaluation team, to measure children's mathematics, spatial language, and mental rotation skills before and after the intervention. The spatial tasks are based on existing assessments (Farran & Atkinson, 2016; Gilligan-Lee et al., 2019; Gilligan-Lee et al., 2021) previously used one-to-one with a researcher, and are being adapted to be appropriate for whole-class administration.

The mathematics measures will contain items formed by various well validated measures, such as White Rose, SATs, KS1 papers, and Testbase, including geometry and problem solving.

School staff will be trained on how to administer the assessment measures by the SPACE team as part of their half-day training and will be provided with a full manual to ensure consistent administration. The assessment measures will be administered by teaching staff in each school during normal class time, separate from delivery of SPACE sessions. The assessment measures will take a maximum of 45-minutes to complete. Schools will be instructed to administer them in either one single session or in two sessions (within the same week). The sequence in which the different measures should be administered will be fixed. More information on the purpose and administration of the child assessment measures can be found in the data collection section.

Fidelity

We will use a combination of data to assess whether SPACE is delivered as intended at each school site. A composite fidelity score for each school will be calculated based on attendance and delivery data, teacher survey responses, and interviews.

Key measures of fidelity will be developed in further work and will include:

- attendance: teaching staff attend training and implementation support sessions
- dosage: delivery of twelve sessions delivered twice weekly for six weeks lasting 30 minutes each (with flexibility to allow the twelve sessions to be delivered over eight weeks with a maximum of three sessions per week)
- adherence to SPACE strategies / quality of delivery: teaching staff use of spatial prompts to support children's problem-solving, and children working autonomously on Lego® models.

Data collection

This evaluation will draw on several research methods to answer our key research questions. Table 2 below provides a full summary of the research questions that each data collection method will answer. We will collect the following data:

- **Administrative programme data**, including attendance at training and delivery registers, will be collected by the SPACE delivery team in fortnightly support sessions provided by the SPACE team to teachers and teaching assistants. This data will help us to understand how SPACE is implemented and whether it is delivered with fidelity.

- **Teaching staff survey at three time points**. The survey will assess 1. The feasibility and acceptability of SPACE, 2. Knowledge of, confidence in, and use of

teaching spatial skills and 3. Perceptions of impacts of SPACE for children. All teaching staff involved in the evaluation will be invited to complete the survey. The survey will be administered online by the evaluation team using Qualtrics. Survey 1 will be completed immediately after the teacher training sessions[3] in September, survey 2 will be completed immediately after the end of delivery and completion of the child assessments in November and December, and survey 3 will be completed towards the end of the following term in March/April. Survey items have been carefully designed to prevent ceiling effects at baseline so that we can detect change over time. Measures of confidence are based on measures previously successfully tested with reception and Key Stage 1 teachers, which showed low baseline responses for confidence and perceived importance of spatial skills. Teachers reported low levels of confidence when asked about their confidence in defining spatial reasoning (64% answered 'not at all confident' or 'a little confident' while only 3% answered 'very confident') (Bates et al., 2023). We will measure teachers' perceived importance of spatial reasoning using sufficiently scaled options to allow for granular responses and avoid a heavy weighting on 'very important'. For this reason, we do not anticipate ceiling effects at baseline. We expect a minimum completion rate of 100% (N=28) at time 1, 75% at time 2, and 50% at time 3. The survey will require around 15 minutes for completion, at each stage.

- **Observations** of two training sessions, four delivery support sessions, up to four assessments delivery[4], and four SPACE sessions in classrooms to aid the evaluation team's understanding of the programme, as well as to assess whether it is implemented as intended and the sufficiency of the training and support available for teaching staff. Observations will be captured on a structured pro-forma in written notes by researchers. They will not involve visual or audio recording as this would be intrusive and require specific parental consents which would be onerous for schools to administer. Schools will be purposively sampled to reflect the variety in school type, size, and location. Observations will take place across the duration of the trial, to capture implementation issues at all stages.

- **Semi-structured interviews** with trained teaching staff at all schools (one interview per school with either a teacher or a teaching assistant, 15 total balanced between the two staff roles) and senior leadership team representatives at a sub-set of schools (eight schools, purposively sampled across school type, size, and location) to assess the feasibility of implementation of SPACE, barriers and facilitators of implementation, sufficiency of support provided, and perceptions of impacts of SPACE for teaching strategies and children. Interviews will require around 30-45 minutes and will be audio-recorded and transcribed verbatim, for full analysis. Interviews will take place by phone or virtual platform toward the end of delivery and be conducted by a member of the evaluation team.

[3] Survey 1 was initially planned to be delivered at the start of the teacher training sessions, to capture teachers' knowledge and perceptions before training. However, due to an administrative error, the baseline survey was instead administered by email immediately after training.. This could have implications for the way that some questions will be interpreted (see Section 2 about 'experience of teaching spatial skills, Q12-16 of Appendix B. The fact that the baseline data was collected after the training will be noted in the report, and taken into account in the interpretation and reporting of results.

[4] The initial intention was to observe a small number of pre-and two post-assessment sessions. Due to scheduling challenges and the importance of not delaying the assessments, it was not possible to schedule pre-assessment observations. We plan to observe at least two post-assessments to understand the feasibility of delivering the assessments but the results and interpretation may not be generalisable to pre-assessments.

- **Group interviews** with the SPACE delivery team (approx. five team members) to understand their experiences of training, implementation challenges, and the readiness of the programme for a larger efficacy trial. Group interviews will last up to an hour, at three separate timepoints. Group interview 1 will be held with the core SPACE development team shortly after the initial teacher training sessions, group interview 2 will be held with the research assistant and postdoc in the second half of delivery to explore implementation issues raised in the fortnightly support sessions for staff, and group interview 3 will be held with the development team after delivery. All interviews will be audio-recorded and transcribed verbatim, for full analysis.

- **Pre-post child assessment measures** to assess the feasibility of administering whole-class measures of spatial and mathematics skills, to perform preliminary validation of the measures for future evaluations, and to identify evidence of promise. These will be designed by the Surrey team and will be based on validated measures of spatial and maths skills. They will be paper-based, completed by each child individually during class time, and administered by the class teacher. All children involved in the evaluation will be asked to complete the assessment measures, with an expected response rate of N=450 as the assessment measures will be delivered during class time. Assessments will require around 45 minutes for completion and can be administered either in a single session or in two sessions within the same week, at the teacher's discretion. School staff will be trained on the assessment measures during the half-day of training and will be supported to administer the assessment measures by the SPACE delivery team. They will also be provided with a thorough manual including step-by-step instructions. The evaluation team will also observe some class-time assessment activity to understand the feasibility for schools of administering the tests. The evaluation team will score and digitise the paper assessments for analysis.

Table 2. Evaluation matrix

		RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7	RQ8	RQ9	RQ10
Programme monitoring data		*		*							
Teaching staff survey		*	*		*	*	*	*			
Observations	Training sessions		*	*							
	Support sessions		*	*							
	SPACE sessions		*	*							
	Child test sessions										*
Interviews	1:1: teaching staff	*	*		*	*		*	*		
	1:1: SLT	*	*	*	*		*				
	Group: delivery team			*						*	*
Pre-post child outcome measures											*

Data analysis

Each data source collected in the evaluation will be analysed separately, then triangulated to identify areas of difference and reinforcement to substantiate and explain findings.

Administrative data: administrative data will be analysed using descriptive statistics and as part of the fidelity composite scoring described below.

Teaching staff surveys: survey responses will be analysed with descriptive statistics and with a repeated measures ANOVA and host-hoc analysis to establish change over time. Due to the sample size limitation (approx. *N* = 30), results will be interpreted as indicative. Responses to any open questions will be coded.

Observations: during observations, researchers will complete a structured pro forma with written notes. Subsequently, these data will be thematically coded using a deductive approach and analysed descriptively to assess fidelity, implementation issues, and children's engagement overall as well as inter-site variation on these dimensions.

Semi-structured interviews and group interviews: transcripts will be analysed using the Framework (Gale et al., 2013; Ritchie et al., 2013) thematic content analysis approach, with mainly deductive analysis (based on implementation dimensions and research questions) and some inductive analysis, and with within-group and between-group comparisons.

Child outcome measures: for each child assessment, change from pre- to post-intervention will be analysed using an ANCOVA to account for any differences by school, in which the dependent variable will be the post-intervention score, the pre-intervention score will be the covariate, and school will be entered as an independent variable. We will report on the range and distribution of results including mean and standard deviation, and including any floor or ceiling effects per assessment (mathematics, mental rotation, language production, language comprehension) at pre- and post- assessment.

Fidelity monitoring: a composite fidelity score will be assigned to each school based on pre-defined criteria to be established in collaboration with the delivery team. These criteria will be assessed using data from the administrative data and teaching staff surveys.

Ethics and registration

- Ethical approval for the delivery of the SPACE programme in schools has been granted by the University of Surrey ethics committee.
- The evaluation of the SPACE programme has been granted a favourable opinion by the Social Research Association ethics appraisal service.

As a pilot trial with the aims of establishing the feasibility of delivery and evaluation, this trial will not be registered.

All adult participants will be provided with information sheets and we will collect full ethical consent before collecting survey or interview data. These documents explain the research in plain language, and participants will be given the opportunity to ask clarifying questions before providing their data. We will also provide clear steps to follow if they wish to end their participation or withdraw their data from the research.

Consent for the participation of children in the study will be provided by the Headteacher of each school, who will be given a full information sheet regarding delivery and evaluation activities. Parents of participating classes will then be provided with an information sheet describing the research in plain language, with clear steps to follow if they wish to opt their child out of any data collection activities.

The evaluation team will take care to protect the anonymity of all research participants and no identifiable information will be included in public outputs or reports. However, this pilot is only being conducted is 15 schools within pre-specified geographic areas, and schools will attend joint training sessions, meaning settings or staff may be identifiable. This risk to anonymity will be expressed to all participating schools at the start of the project.

Data protection

CEI store and process all data in line with GDPR And the UK Data Protection Act 2018. All data procedures are overseen by our Data Protection Officer. CEI's legal basis for processing personal data is legitimate interest. The University of Surrey's legal basis for processing personal data is public task.

Staff involved in the evaluation will be assigned a unique identifier by CEI, which will be used to identify survey responses. CEI will hold the key linking staff names and their unique identifier in order to link surveys over the three time points. This key will be securely stored separately from the survey data.

The paper child assessments will be shared by schools by secure courier delivery with CEI, where a unique identifier will be assigned and the paper surveys will be digitised, before the paper copies are securely destroyed. CEI will hold the key linking children's names and their unique identifier in order to link the assessments over the two time points. This key will be stored securely separately from the assessment data.

Pseudonymised quantitative survey and assessment data will be shared between the two institutions, but the University of Surrey will not have access to the unique identifier key required to identify staff or children. Interview data will not be shared between the institutions. Personal data will be held by CEI for 2 years after which point it will be securely destroyed. Personal data held by the University of Surrey will be destroyed after 6 years.

A data privacy impact assessment has been undertaken for this project. All information is securely stored on a dedicated drive at the respective institution, accessible only to the CEI or University of Surrey research team.

All participating schools, teachers, and parents of children will be provided with a data privacy notice which details all their rights as data participants, including their rights to withdraw data from the evaluation. All interviewees will be given the data privacy notice and verbally reminded about the anonymous and confidential handling of their data at the start of each survey and interview.

Personnel

Evaluation team:

Jane Lewis, Centre for Evidence and Implementation, Managing Director, Project Director

Amy Hall, Centre for Evidence and Implementation, Advisor, Project Manager and Lead Researcher

Emma Wills, Centre for Evidence and Implementation, Advisor, Project Researcher

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Ann Dowker, University of Oxford, Research lecturer, Subject area expert

Delivery team:

Professor Emily Farran, University of Surrey, Principal Investigator, delivery team lead

Professor Camilla Gilmore, Loughborough University, Chief Investigator, delivery team

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Professor Derek Bell, Learnus, Chief Investigator, delivery team

Dr Marija Živković, University of Surrey, Postdoctoral researcher

Rachel Baxter, University of Surrey, Project Officer

Risks

The main risks to this project are detailed in Table 3.

Table 3. Anticipated risks and mitigations

Risk	Likelihood / impact	Mitigation / contingency
Delays in school recruitment	Medium / Low	• Support SPACE delivery team with recruitment documentation • No-cost extension if necessary
Delays in securing ethical approval	Low / Medium	• Realistic timescale allowed in timetable

Risk	Likelihood / impact	Mitigation / contingency
		• Team members are highly experienced in securing ethical approval
Gaps in programme data collected by SPACE delivery team	Medium / Medium	• Support delivery team • Ensure schools understand rationale for programme data requests • Take over responsibility to support collection of data if necessary
Low response rate to the survey / interviews	Low / Medium	• Early liaison with schools, clear MoU and information sheets • Embed first wave of survey in training • Follow up by phone/email • Realistic qualitative samples • Flexibility in interview timing/mode
Data breach	Low / Medium	• CEI staff trained in data protection procedures • CEI systems are secure • Clear data management protocols • Data transferred and held securely • Paper surveys to be transferred using secure courier delivery
Staff turnover in schools	Low / Low	• Adapt evaluation plan as necessary e.g. if further teacher/teaching assistant training sessions are required
Evaluation staff absences or turnover	Low / Low	• CEI has a very stable staff group and over 40 research staff members plus associates and consultants • Team-based approach provides effective cover for absences
Low response rate to child outcome measures and/or high levels of missing data	Low / Medium	• Thorough guidance for teachers to facilitate administration • Ensure schools understand rationale for programme data requests • Option to administer in 2 shorter sessions to facilitate integration into lesson time • The delivery and evaluation teams will observe early sessions to identify and resolve serious issues that arise
School closure and teaching returning to	Low/High/Medium	• Unlikely that SPACE could be administered by teachers online so

Risk	Likelihood / impact	Mitigation / contingency
online due to Covid resurgence		evaluation would have to be postponed

We will develop and maintain a risk register, which will help us to anticipate and communicate risks in a timely way and to set out mitigation strategies.

Timeline

Dates	Activity	Staff leading / responsible
March-August 2023	Schools sign up to the project	University of Surrey
September 2023	Schools distribute parent/carer information sheet	Schools
September 2023	SPACE Training (half day)	University of Surrey
September 2023	Teacher survey 1	CEI
September 2023	Pre-intervention child assessment	CEI
September-December 2023	SPACE delivery	Schools overseen by University of Surrey
September-December 2023	Fortnightly support sessions for school staff	University of Surrey
September-December 2023	Administrative data collection	University of Surrey and CEI
September-December 2023	Observations	CEI
September-December 2023	Teaching staff and SLT interviews	CEI
October-December 2023	Teacher survey 2	CEI
December 2023	Post-intervention child assessment	CEI
March-April 2024	Teacher survey 3	CEI
July 2024	Results of project published (estimated)	CEI

References

Allen, L. & Dowker, A. (2022). Spatial working memory counts: evidence for a specific association between visuo-spatial working memory and arithmetic in children. *International Electronic Journal of Elementary Education,* 14, 199-211.

Bates, K. E., Williams, A. Y., Gilligan-Lee, K. A., Gripton, C., Lancaster, A., Williams, H., ... & Farran, E. K. (2022). Practitioners' perspectives on spatial reasoning in educational practice from birth to 7 years. British Journal of Educational Psychology.

Bower, C., Odean, R., Verdine, B. N., Medford, J. R., Marzouk, M., Golinkoff, R. M., & Hirsh-Pasek, K. (2020). Associations of 3-year-olds' block-building complexity with later spatial and mathematical skills. *Journal of Cognition and Development,* 21(3), 383-405.

Bower, C., Zimmermann, L., Verdine, B., Toub, T. S., Islam, S., Foster, L., & Golinkoff, R. M. (2020). Piecing together the role of a spatial assembly intervention in preschoolers' spatial and mathematics learning: Influences of gesture, spatial language, and socioeconomic status. *Developmental Psychology*, 56(4), 686–698

Cornu, V., Schiltz, C., Pazouki, T., & Martin, R. (2017). Training early visuo-spatial abilities: A controlled classroom-based intervention study. *Applied Developmental Science,* 6, 1–21.

Cornu, V., Schilz, C., Martin, R. & Hornung, C. (2018). Visuo-spatial abilities are key for young children's verbal number skills. *Journal of Experimental Psychology,* 166, 604-620.

Dowker, A. (2005). Early identification and intervention for students with mathematics difficulties. *Journal of Learning Disabilities,* 38, 324–332.

Dowker, A. (2017). Interventions for primary school children with difficulties in mathematics. In J. Sarama, D. Clements, C. Germeroth & C.l Day-Hess (eds.) Advances in Child Development and Behavior, Vol. 53: *The Development of Early Mathematics Education.* New York, NY: Elsevier (pp. 255-287)

Farran, E. K., & Atkinson, L. (2016). The development of spatial category representations from 4 to 7 years. British Journal of Developmental Psychology, 34(4), 555-568.

Gale, N. K., Heath, G., Cameron, E., Rashid, S., & Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC medical research methodology*, 13(1), 1-8.

Gibbons, A. (2020, July 1). *DfE concedes 'importance' of space and shape in EYFS*. Tes Magazine. Retrieved April 20, 2023, from https://www.tes.com/magazine/archive/dfe-concedes-importance-space-and-shape-eyfs

Gifford, S. (2019, August 19). *The case for Space in the early years* - BSRLM. BSRLM. Retrieved April 20, 2023, from https://bsrlm.org.uk/the-case-for-space-in-the-early-years/

Gilligan, K. A, Hodgkiss, A, Thomas, M. S, Farran, E. K (2019). The developmental relations between spatial cognition and mathematics in primary school children*, Developmental Science,* 22, 1-19

Gilligan-Lee, K. A., Hawes, Z. C., & Mix, K. S. (2022). Spatial thinking as the missing piece in mathematics curricula. *npj Science of Learning*, 7(1), 10.

Gilligan-Lee, K. A., Hodgkiss, A., Thomas, M. S., Patel, P. K., & Farran, E. K. (2021). Aged-based differences in spatial language skills from 6 to 10 years: Relations with spatial and mathematics skills. *Learning and instruction*, 73, 101417.

Gilmore, C., & Cragg, L. (2014). Teachers' understanding of the role of executive functions in mathematics learning. *Mind, Brain, and Education*, 8(3), 132-136.

Gross, J., Hudson, C. & Price, D. (2009). The Long-Term Costs of Numeracy Difficulties. London: *Every Child a Chance Trust*.

Hawes, Z.; Gilligan-Lee, K. & Mix, K. (2022). Effects of spatial training on mathematics performance: a meta-analysis. *Developmental Psychology*, 58, 112-137.

Janus, M., & Duku, E. (2007). The school entry gap: Socioeconomic, family, and health factors associated with children's school readiness to learn. *Early education and development,* 18(3), 375-403.

Lowrie, T., Logan, T., & Ramful, A. (2017). Visuospatial training improves elementary students' mathematics performance. *British Journal of Educational Psychology*, 87, 170 –186.

Mix, K. S., Levine, S. C., Cheng, Y., Stockton, J. D. & Bower, C. (2021). Effects of spatial training on mathematics in first and sixth grade children. *Journal of Educational Psychology*, 113, 304-314.

Moss, J., Bruce, C.D., Caswell, B., Flynn, T. & Hawes, Z. (2016). Taking shape: activities to develop geometric and spatial thinking. *Pearson Canada Inc.,* pp. 13–16.

Ritchie, J., Lewis, J., McNaughton Nicholls, C., & Ormston, R. (2013). Analysis: Principles and processes. *In Qualitative Research Practice.* SAGE Publications Ltd.

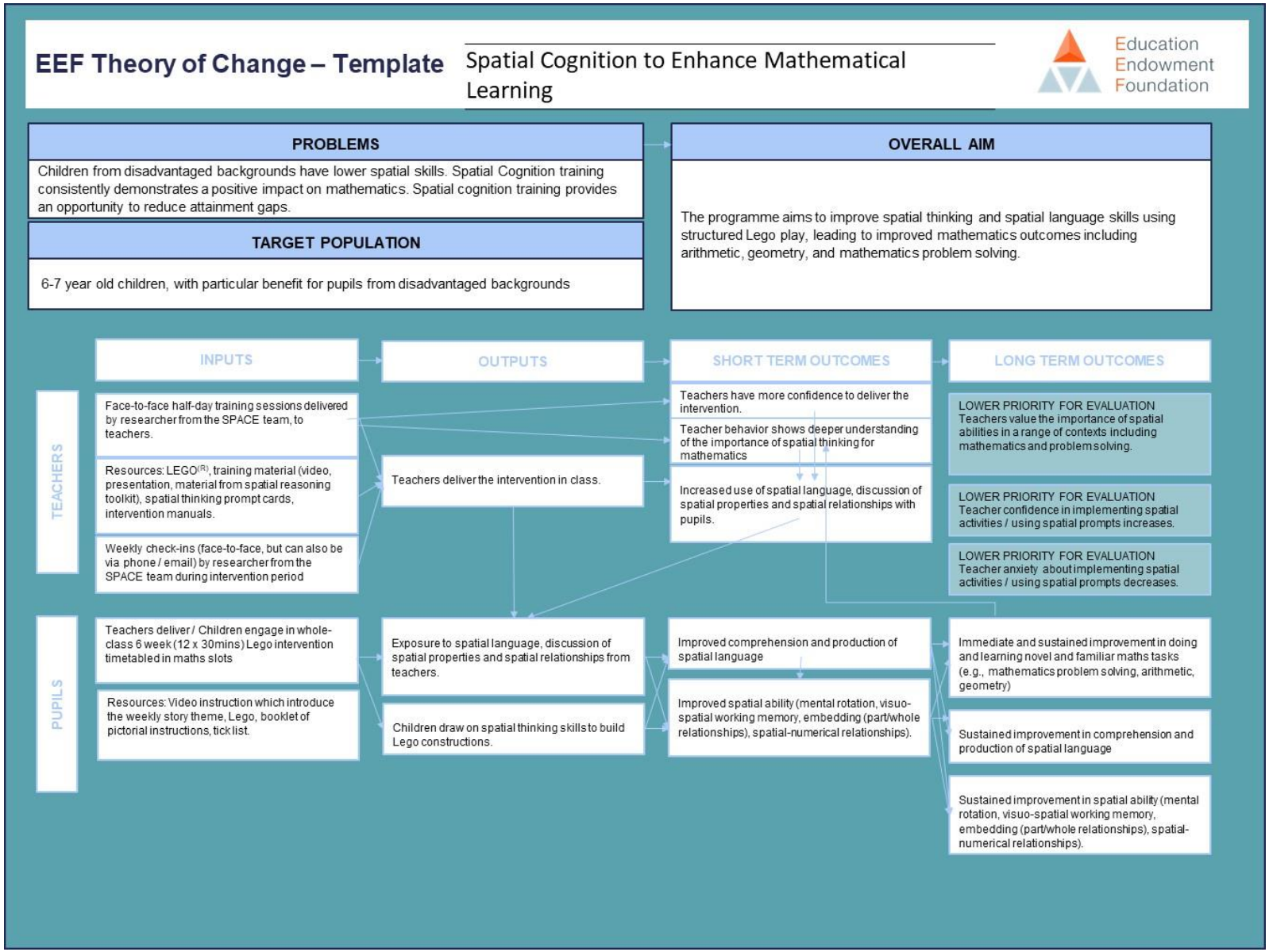
Ritchie, S. J., & Bates, T. C. (2013). Enduring links from childhood mathematics and reading achievement to adult socioeconomic status. *Psychological science*, 24(7), 1301-1308.

Schmitt, S. A., Korucu, I., Napoli, A. R., Bryant, L. M., & Purpura, D. J. (2018). Using block play to enhance preschool children's mathematics and executive functioning: A randomized controlled trial. *Early Childhood Research Quarterly,* 44, 181–191.

Verdine, B. N., Golinkoff, R. M., Hirsh-Pasek, K., Newcombe, N. S., Filipowicz, A. T., & Chang, A. (2014). Deconstructing building blocks: Preschoolers' spatial assembly performance relates to early mathematics skills. *Child Development,* 85(3), 1062–1076.

Weiner, B. J., Lewis, C. C., Stanick, C., Powell, B. J., Dorsey, C. N., Clary, A. S., ... & Halko, H. (2017). Psychometric assessment of three newly developed implementation outcome measures. *Implementation Science,* 12, 1-12.

Appendix A – Theory of Change



Appendix B- SPACE Teacher survey

The survey will be completed by teachers immediately after the SPACE training day for T1, and with a link sent by email at T2 and T3. We have indicated which questions are to be used at each timepoint, although the T3 survey will be reviewed and finalised after main implementation fieldwork.

Welcome to the SPACE teaching staff survey. Please read this information carefully before continuing to the survey.

The purpose of this survey is to understand teachers and teaching assistants' knowledge and understanding of teaching spatial skills in the classroom. It should take no more than 10 minutes to complete.

The survey is being undertaken by the Centre for Evidence and Implementation and forms part of the evaluation of SPACE, funded by the Education Endowment Foundation, to assess whether the SPACE programme is feasible and appropriate to use in Year 2 classrooms.

- *Information sheet content*
- *Consent form content*

Thank you for reading the information sheet provided. If you have any questions, please ask a member of the evaluation or delivery teams.

If you have any questions about the Information Sheet, please ask the researcher before you make your decision. You will be given a copy of this Consent Form and the Information Sheet to keep and refer to at any time.

You must agree to all of the following statements in order to proceed to the survey. If you would like to take part but are not sure about any of the statements, please talk to a member of the delivery or evaluation team.

Please be aware that some of the statements below apply to the interview which you may be invited to in the future.

1 I confirm that I have read and understood the information sheet dated Version 2 - 28/02/2023 for the above study. I have had the opportunity to consider the information and asked questions which have been answered satisfactorily.
2 I understand that my participation is voluntary and that I am free to withdraw at any time during the study without giving any reason. Furthermore, I understand that data already collected can only be withdrawn up to 20th December 2023
3 I understand that information I provide may be subject to review by responsible individuals from the Centre for Evidence and Implementation or the University of Surrey and/or regulators for monitoring and audit purposes.
4 If I take part in an interview, I consent to it being audio-recorded, transcribed by a transcription agency, and anonymised quotes being used in the report, without including details that could identify me.

5 If I take part in a survey, I consent to my personal data being shared with the delivery team at the University of Surrey for the purposes described in the information sheet.
6 I understand that information I provide will be used in various anonymised outputs, including the evaluation report, evaluation summary and other publications.
7 I understand that my personal data, including this consent form, which link me to the research data, will be kept securely in accordance with data protection guidelines, and only be accessible to the immediate research team or responsible persons at the Centre for Evidence and Implementation and the University of Surrey.
8 I understand any personal contact details collected about me, such as my phone number and address, will not be shared beyond the study team.
9
I agree to take part in this study.

Your school and role

1. Please provide your full name
   - *This is so that we can link your survey responses to future surveys. Once surveys have been linked, we will remove all personal data from them.*
     - Open text box

2. Please select the name of your school from this drop-down list:
   - Drop down with the 15 school names

3. What is your role in the school?
   - Teacher
   - Teaching assistant
   - Senior leader with teaching role
   - Senior leader without teaching role
   - Other - please write in

4. Will you be working directly with the Year 2 SPACE evaluation class this term?
   If you are not sure, please confirm with the delivery team before proceeding
   - Yes
   - No

5. Are you the SPACE delivery lead in your school?
   - Yes
   - No
   - Don’t know

6. If you also have a leadership role within your school, please tell us what it is. T1
   Please select all that apply
   - Maths lead
   - Other subject lead
   - Headteacher
   - Deputy headteacher
   - KS1 lead

- Other [text box]
- I don't have a leadership role

7. TEACHERS ONLY: For how long have you been a qualified teacher? T1
   Please select one response
   - I am not yet a qualified teacher
   - Under 2 years
   - 2-5 years
   - 6-10 years
   - Over 10 years

8. TEACHERS ONLY And for how long have you worked at your current school as a teacher? T1
   Please select one response
   - Under 2 years
   - 2-5 years
   - 6-10 years
   - Over 10 years

9. TEACHING ASSISTANTS For how long have you worked as a teaching assistant? T1
   Please select one response
   - Under 2 years
   - 2-5 years
   - 6-10 years
   - Over 10 years

10. TEACHING ASSISTANTS And for how long have you worked at your current school in any role? T1
    Please select one response
    - Under 2 years
    - 2-5 years
    - 6-10 years
    - Over 10 years

11. Is your school currently using any of these maths programmes? T1
    Please select any that apply
    - NCETM mastering number
    - Ark mastery
    - 1stClassNumber
    - Other [text box]
    - Don't know

Your experience of teaching spatial skills

These next questions are about your confidence and practices in relation to teaching spatial reasoning and spatial skills.

If you are a teacher, when answering the following questions please think about the classes you have taught over the last 12 months.

If you are a teaching assistant, when answering the following questions please think about the classes you have supported over the last 12 months.

12. How important do you think spatial reasoning is for the development of children's mathematics skills? Please select an option on a scale of 1 to 10, where 1 is 'not at all important' and 5 is 'extremely important'
    Please select one
    - 1 Not at all important
    - …
    - 10 Extremely important
    -

13. If you were asked to explain what spatial reasoning is to someone else, how confident would you be in your definition?
    Please select one
    - (1) not confident at all – I am not sure how to define spatial reasoning
    - (2) a little confident – I have a basic idea of how to define spatial reasoning
    - (3) confident – I have a good idea of how to define spatial reasoning
    - (4) very confident – I have a very clear idea of how to define spatial reasoning
    - Don't know

14. Please write in your definition of spatial reasoning
    - Free text box (Max 250 characters)

15. How confident are you in your ability to incorporate spatial reasoning into your maths teaching or classroom support?
    Please select one
    - Not confident at all
    - A little confident
    - Confident
    - Very confident
    - Don't know

16. How often do you typically use each of the following activities in your teaching or classroom support?
    MATRIX LAYOUT - RESPONSE CATEGORIES ARE COLUMN HEADING, ACTIVITIES ARE ROWS

Please not that this question is about your general activities in the classroom. These activities are not directly part of the SPACE programme and will not be the focus of the training today.

RESPONSE CATEGORIES

- Not at all
- Once or twice a term
- Once a week
- A few times per week
- Every day
- More than once a day
- Don't know /can't say

ACTIVITIES

- Using and explicitly teaching relational words e.g., 'in', 'on', 'between', 'next to', 'under', 'big', 'small', ‘above’
- Building 3D shapes with construction sets e.g., tiles, blocks, Lego, multi-link cubes, magnetic shapes
- Using a number line with children
- Practising with turning and flipping shapes or fitting shapes together e.g., jigsaw puzzles
- Directing a toy or another child through a maze
- Comparing and describing the differences between two different pictograms or charts
- Measuring shapes and objects using a ruler
- Using drawing, counters and/or arrays to solve multiplication and division questions

17. If there is anything else you would like to tell us about your experience with teaching spatial reasoning, please write in the box below.
    - [open text box]

    Thank you very much indeed for completing this survey.

[Close survey at T1] Thank you very much indeed for completing the survey. If there is anything else you would like to tell us about your involvement in SPACE, please write in the box below.