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]

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.

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. **Does SPACE 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

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[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 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.

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 at the beginning of the SPACE training session, before any content is shared, survey 2 will be completed towards the end of SPACE delivery, and survey 3 will be completed towards the end of the following term. 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=30) 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, 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.

- **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.

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 secturely separately from the assessment data.

Pseudonymised quantitative survey and assessment data will be shared between the two institutions, but the University of Surrvey 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

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

Dr Katie Gilligan-Lee, University of Surrey, Chief Investigator, delivery team

Professor Tim Jay, Loughborough University, Chief Investigator, delivery team

Professor Denis Mareschal, Birkbeck, University of London, Chief Investigator, delivery team

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

Risk	Likelihood / impact	Mitigation / contingency
School closure and teaching returning to online due to Covid resurgence	Low/HighMedium	• Unlikely that SPACE could be administered by teachers online so 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 – Theory of Change

EEF Theory of Change – Template — Spatial Cognition to Enhance Mathematical Learning

Education Endowment Foundation

PROBLEMS
Children from disadvantaged backgrounds have lower spatial skills. Spatial Cognition training consistently demonstrates a positive impact on mathematics. Spatial cognition training provides an opportunity to reduce attainment gaps.

TARGET POPULATION
6-7 year old children, with particular benefit for pupils from disadvantaged backgrounds

OVERALL AIM
The programme aims to improve spatial thinking and spatial language skills using structured Lego play, leading to improved mathematics outcomes including arithmetic, geometry, and mathematics problem solving.

	INPUTS	OUTPUTS	SHORT TERM OUTCOMES	LONG TERM OUTCOMES
TEACHERS	Face-to-face half-day training sessions delivered by researcher from the SPACE team, to teachers.	Teachers deliver the intervention in class.	Teachers have more confidence to deliver the intervention.	LOWER PRIORITY FOR EVALUATION Teachers value the importance of spatial abilities in a range of contexts including mathematics and problem solving.
	Resources: LEGO(R), training material (video, presentation, material from spatial reasoning toolkit), spatial thinking prompt cards, intervention manuals.		Teacher behavior shows deeper understanding of the importance of spatial thinking for mathematics	LOWER PRIORITY FOR EVALUATION Teacher confidence in implementing spatial activities / using spatial prompts increases.
	Weekly check-ins (face-to-face, but can also be via phone / email) by researcher from the SPACE team during intervention period		Increased use of spatial language, discussion of spatial properties and spatial relationships with pupils.	LOWER PRIORITY FOR EVALUATION Teacher anxiety about implementing spatial activities / using spatial prompts decreases.
PUPILS	Teachers deliver / Children engage in whole-class 6 week (12 x 30mins) Lego intervention timetabled in maths slots	Exposure to spatial language, discussion of spatial properties and spatial relationships from teachers.	Improved comprehension and production of spatial language	Immediate and sustained improvement in doing and learning novel and familiar maths tasks (e.g., mathematics problem solving, arithmetic, geometry)
	Resources: Video instruction which introduce the weekly story theme, Lego, booklet of pictorial instructions, tick list.	Children draw on spatial thinking skills to build Lego constructions.	Improved spatial ability (mental rotation, visuo-spatial working memory, embedding (part/whole relationships), spatial-numerical relationships).	Sustained improvement in comprehension and production of spatial language
				Sustained improvement in spatial ability (mental rotation, visuo-spatial working memory, embedding (part/whole relationships), spatial-numerical relationships).