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The Embodying Mathematics Project[1]: Report

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[1] The project has been further developed as Ensemble Maths

Acknowledgements

The Embodying Mathematics Project, 2015-2017, was a collaboration between Complicite theatre company and Sheffield Hallam University. The project was undertaken with financial support of the *John Lyon's Charity*, the *Paul Hamlyn Foundation* and *Sheffield Hallam University* through an Impact Fellowship Grant. Following the completion of the project, Complicite has continued to develop this work as Ensemble Maths

The time and commitment of teachers and support of the school leaders from the following schools was essential to the project's success:

London

Torriano Primary School 2015/16 & 2016/ 17

St Mary's and St John's CE School, 2015/16 & 2016/17

Christopher Hatton Primary School 2016/17

Edith Neville Primary School 2016/17

Fitzjohn's Primary School 2016/17

Rhyl Primary School 2016/17

St Mary's Bryanston Square 2015/16

Camrose Primary School 2015/16

Sheffield

Lydgate Lane Junior School 2016/17

Hunter's Bar Junior School 2016/17

Project team

Dina Mousawi , Hilary Povey, Mark Boylan, Nick McIvor, Poppy Keeling, Shane Shambhu, Victoria Gould (first name alphabetical order, details of members of the project team and roles are provided in section 3.2.1.)

Additional support

In addition the project was supported by a project steering group (Professor Leon Feinstein, Professor Marcus du Sautoy, Judith Dimant and Bavaani Nanthabalan) and an external research advisory group, Professor Anne Watson, Professor John Leach and Dr Alf Coles and Sally Pearse. Claire Christie of Ashley Down Primary School advised on links between activities and the National Curriculum in the London 2015/16 phase.

Picture credit front cover: Sarah Ainslie

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Glossary

Circle time	PSHE activity supporting classroom relationships and to develop social and oracy skills
EMP	Embodying Mathematics Project
Ensemble	Drama practice that emphasises actors working together rather than individual performance, also the name for the group working together
GMA	Group Mastery Activity - ensemble activity done in a classroom
KS2	Key Stage 2, English primary years 3-6 7-11 years old
Lesson	An EMP lesson. A 'lesson' consisted of a set of linked activities that might take more than a single school lesson to complete
PSHE	Personal Social and Health Education
SHU	Sheffield Hallam University

Report Summary

Background

The Embodying Mathematics Project (EMP) (2015-2017) was a collaboration between Complicite theatre company and Sheffield Hallam University (SHU) funded by The John Lyon's Charity, the Paul Hamlyn Foundation, and an SHU Impact Fellowship Grant. The project focused on developing drama informed mathematical movement activities drawing on previous work by Complicite and activities developed in mathematical education contexts.

Prior to the EMP, Complicite had developed ensemble movement mathematics activities during the process of devising *A Disappearing Number*, its 2007 production which centres on the history of Srinivasa Ramanujan, a 20th century mathematician, and on the idea that mathematics is a creative and 'beautiful' discipline. These activities, initially used in the rehearsal room, were developed into a series of workshops for schools. In 2015, Complicite invited proposals to develop this work and members of the Mathematics Education Research Group at Sheffield Hallam University proposed a combined curriculum and professional development project, focused on primary mathematics in the 7-10 years old age range, called the *Embodying Mathematics Project*.

EMP drew on: evidence that engaging in drama, in general, can impact positively on pupils' attitudes to school and their mathematical attainment; conceptualisation of ensemble or rehearsal room pedagogy; developments in mathematics education that promote collaborative learning; and recent interest in embodiment in mathematics education. In addition, the EMP sought to develop and add to previous movement based mathematical activities.

The project was developed in the primary mathematics context, in which the curriculum is often decontextualised and lacks meaning, and with pupils increasingly grouped according to perceived mathematical ability. This means that learners can become alienated from mathematics, from other people and from themselves. In addition, many primary teachers have themselves had alienated experiences of school mathematics and report anxiety about teaching the subject linked to their own negative experiences of mathematics in school and beyond.

Aims

The project sought to:

- design, develop and evaluate curriculum materials, activities and pedagogy informed by movement based and ensemble practices
- develop appropriate professional development activities
- examine how teachers can mediate embodied and ensemble learning to impact on pupil learning and attitudes
- identify appropriate evaluation methodologies and tools for assessing outcomes of embodied activities

- assess outcomes for teachers of engagement in professional development
- and assess learning and social outcomes for pupils.

Project outline

The overall project consisted of three sub-projects that were mutually supportive but implemented as distinct activities:

a. Year 1 2015/16 London 4 schools, 8 teachers - Complicite and SHU co-design and implementation
b. Year 2 2016/17 Sheffield 2 schools, 6 teachers - Complicite and SHU design, Complicite implementation
c. Year 2 2016/17 London 6 schools, 10 teachers - Complicite design and implementation.

SHU led the evaluation in all cases.

A total of 24 teachers, and 600-700 children, drawn from 9 schools in London and 2 schools in Sheffield, participated in the project.

The EMP core team comprised Complicite practitioners, an experienced mathematics curriculum developer and mathematics education academics and evaluators from SHU, and, in the first year, support from an experienced school based professional developer.

Components

Components of the programme were:

- Complicite workshops lasting 1-2 hours, led by Complicite practitioners and offering both learning experiences for pupils and professional development opportunities for teachers.
- Lesson activities designed to be used either inside or outside the classroom.
- Group Mastery Activities (GMAs) developed for the second year of the project in response to Year 1 teachers' difficulties securing enough time in spaces large enough to perform EMP activities regularly (GMAs reproduce aspects of Complicite workshop activities within a classroom setting).
- 'Being a Mathematician' used in London in Year 1. Being a Mathematician aimed to promote a set of dispositions that embodied and ensemble activities could potentially cultivate and ones for which there was evidence from meta-cognitive interventions of association with improved mathematical attainment and relationships to mathematics.
- Professional development through day-long workshops and twilight sessions; these were called 'development days' to indicate that although professional development was an important focus, teachers were also supporting the development of materials and activities.
- Performance: in 2016/17 the use of GMAs led to a mathematical 'performance' to other students and/or to parents.

During the first design year of the project in London, materials were developed for 20 lessons[2], organised into four modules, suitable for use with Y3 to Y5 pupils. To enhance the teachers' and students capacity to view mathematics and mathematical activities in new ways a framework focused on ways of 'Being a Mathematician' were developed. Teachers experienced 2.5 days of CPD and 4 twilight sessions.

During the second year in London, the project focused on developing GMAs leading to performance. Teachers experienced 1 day of CPD and 1 twilight session with the project activity taking place over one school term.

In Sheffield schools, the project focused specifically on Y3 pupils, and materials developed in the design year were refined and used by teachers alongside GMAs, with materials for up to 20 lessons being devised. As in London, the year culminated in performance, and on this occasion all participating classes came together to perform and parents were invited. Teachers experienced 4 days of CPD and 3 twilight sessions.

Evaluation

A design evaluation was undertaken to inform development of activities during the project as well as potential future development. Although outcomes were assessed, the main purpose was informative rather than evaluative given the atypical nature of schools' participating and that activities were being piloted.

The project was evaluated using a mixed method design. Evaluation focused on design of embodied activities, teacher professional development outcomes, pupil responses and attitudes. In Sheffield, effect on knowledge of multiples and factors, an area relevant to project activities, was assessed through a short pre and post test.

Data was collected through activities in development days (including audio recording discussions), 7 teacher interviews, surveys of teachers, 4 pupil focus groups, pupil attitude surveys and a mathematics test (in Sheffield). Although the evaluation of impact on attitudes and the test was observational, a comparison with a previous Y3 cohort was undertaken in Sheffield. Recognised statistical analytical processes were used. Due to the nature of the design, findings from the impact evaluation should be treated with caution and causality cannot be inferred.

Implementation and teachers' attitudes to the projects

From surveys, interviews and feedback at development days, the teachers involved in nearly all cases were positive about the project and EMP activities. The value of activities for supporting pupils' collaboration was a particular feature appreciated. As noted above, Complicite workshops became more focused on teacher professional development than pupil experience during the project and this was valued by teachers, particularly where this involved Complicite practitioners and teachers co-leading. One teacher suggested time for

[2] A 'lesson' here is a set of linked activities that might take more than a single school lesson to complete, see 3.2.2.2

debriefing and discussion with practitioners would have augmented learning. Teachers in London 2015/16 valued the conceptual framework for 'Being a Mathematician'

GMAs, an emergent component of the project, were particularly appreciated and noted as an aspect likely to be continued in the future. They could and were used flexibly, including in subjects other than mathematics. Different GMAs were used for either energising or calming the class depending on what was needed. Whilst teachers reported that GMAs were socially challenging for pupils, this led to valuable social learning and created opportunities for reflection with pupils on working together. Teachers reported using them the expected 2-3 times per week, though tended to reduce over time.

Sheffield teachers, who were provided with lesson activities, as well as GMAs, were positive about lesson materials, particularly number focused activities which were found to more easily fit into the curriculum due to current emphases. The way lesson activities were presented was appreciated with materials being easy to use. As anticipated, sets of activities took longer than a lesson to use.

The amount of professional development experienced was viewed as appropriate in all three sub-projects with the full PD days viewed most favourably, and practically engaging in activities as the most useful part of the PD experience. Teachers were also positive about the performance in those sub-projects where it was a component.

Pupil attitudes to the project and project activities

Teachers' perceptions, pupil survey data and pupil focus group data supported the conclusion that the majority of pupils were positive or very positive about activities. There is some association of this with pupils' general enjoyment of mathematics. A minority were less favourably inclined, for some of these this was because they did not find activities mathematically challenging and/or they preferred to work individually.

Constraints, adaptations and supporting factors

Constraints or barriers to implementation included: curriculum and time pressures; the availability of spaces outside the classroom; pupil concentration; and accountability pressures. Supporting factors included: flexible classroom spaces (where found); school orientation and developments compatible with the project, including school leadership support; and teachers' existing capacities and experience.

Professional development outcomes

Professional development outcomes for teachers included:

- increased knowledge about linking mathematics to movement and skills to do this
- extended teaching repertoires more generally
- knowledge about performative possibilities of mathematical activity
- the capacity to develop a learning community in the classroom
- changes in beliefs about mathematical ability
- experiences of teacher agency in developing and adapting activities

- increased understanding of teaching specific mathematical content, skills and knowledge.

There were several individual reports of transformative learning in terms of approach to teaching and view of mathematical ability.

Pupil outcomes

Teachers reported positive influences on pupil attitude to learning saying that GMAs, and project activities more generally, had supported the development of a sense of togetherness in the class. At best engaging in Embodying Maths Project activities broke down patterns of children labelling themselves or each other. Although some pupils resisted ways collaborative ways of working due to their individualised orientation, and other 'vulnerable' pupils - for example EAL or SEN pupils - found the ensemble environment challenging, teachers reported the experience of collaborating as bringing important social learning. This was enhanced by classroom discussions of the value of working in an ensemble way. Teachers explicitly linked project activities to Personal, Social and Health Education (PSHE).

A pupil attitude survey showed no change for pupils participating in London 2017. In Sheffield the number of students who indicated an improved attitude to mathematics was greater than those who indicated a less favourable attitude (13 more pupils with an increase than decrease for pre-affect score and 11 with a higher working with others score). Similar outcomes were found regarding attitudes to working with others in mathematics. However, this outcome must be treated with caution as end of year attitudes compared with the previous cohort showed no significant difference. Given Y3 children in both schools in Sheffield joined the junior schools in Y3, it may be that attitudes in mathematics improve in the two schools anyway, and so this outcome is not conclusive. Further, there was significant flux in attitudes and teachers' reported that Y3 pupils were struggled with the Likert-format assessment.

Teachers considered the activities effective in supporting pupil learning. Evidence from the impact study in Sheffield suggests that in one school there was a small but not statistically significant higher mathematics score than in comparison with a previous year. In the other school, test scores were found to be lower than the previous year and this difference was significant. These outcomes should be treated with caution due to the test used and lack of comparative pre as well as post test data, as well as possible differences due to cohort effects. Note that due to changes in national assessment data it is not possible to compare the cohorts on a separate measure.

In the two schools the average scores were relatively high in the post test (mean of 5.25 and 20% of pupils have a score of 7-10 out of 10). The test was related to the content of lesson activities and GMAs, This indicates that the level of mathematical content in the multiple and factor activities was not challenging for all pupils, as a proportion already understood the content.

Outcomes and implications

1. Design and further development of project components

Professional development: Both formalised professional development activities and engagement in the project had a range of professional development outcomes. The overall balance of encouraging engagment in the substantive mathematical activities and considering their use in classrooms was successful.

The format for PD days that evolved was effective and valued by teachers. Twilights focused only on reflection were less useful. The suggestion to include debriefs or opportunity for discussion with practitioners during workshop visits is worth considering.

Being a Mathematician: This component has potential for development as a distinct initiative.

GMAs. The development of this new component represents a significant success of the project and gave opportunities for developing the ensemble in the classroom. Teachers offered useful advice and suggestions, as well as adaptations that could be incorporated into descriptions of GMAs. If they are to be used beyond Y3 and engage all pupils, attention is needed to considering the mathematical challenge of activities. However, there may be a tension between ensemble experience and the aesthetics of using movement and rhythms work to explore multiples of numbers in the full range required in the KS2 curriculum. This could be explored in future developments.

Lesson activities: These were, in general, positively received though the developed symmetry activities were less successful and should be revisited in future iterations.

Performance: Like GMAs, this was an emergent aspect of the project and both forms - to peers/school community and to parents - were successful.

2. Teacher mediation of activity to support learning and positive relationships to mathematics

Teachers had a key role in mediating activities so they could be used successfully. Important for this were their prior experience, their enthusiasm, and modelling by Complicite practitioners.

3. Development of evaluation tools

A range of evaluation methods and tools were used in the project. Whilst overall these were successful in generating data to inform design, attention in future evaluation should be given to appropriateness of mathematics test(s) and the way pupil attitudes are assessed.

4. Implications and outcomes for teachers, pupils and project design

The project was effective in increasing teachers' capacity to use movement activities to support mathematical learning, as well as gaining an understanding of how to support and foster collaborative learning through ensemble activities. The project led to transformative learning as well as an increase in skills. The former could be enhanced by deepening collaboration between teachers, and between teachers and practitioners.

Teachers reported important outcomes in terms of a sense of class togetherness and the capacity of some individuals to collaborate. As an extension to the EMP, the value of ensemble pedagogy for Y7 pupils transitioning to secondary school is worth further exploration.

Two distinct approaches to developing the project in the future have emerged. The first of these is Embodied Mathematics, conceived as broadly similar to the 2016/17 Sheffield version of the project, in which lesson activities were carried out alongside GMAS. The second approach is Ensemble Mathematics, structured in a similar way to the 2016/17 London project, and focusing on GMAs with lesson activities provided as an optional extra.

Conclusion

The EMP has led to the development of a variety of innovative curriculum activities focused on mathematics and movement. Particularly interesting areas are the extension of movement activities to focus on multiples and factors and the development of GMAs. The project had a number of positive outcomes for teachers and pupils. Importantly, the project led to greater clarity about meanings of ensemble pedagogy and collaborative learning for the designers and teachers. A rich set of mathematical activities were developed, and the school experience of at least 24 teachers and up to 700 pupils was enriched.

1 INTRODUCTION

Complicite theatre company and Sheffield Hallam University (SHU) collaborated to create, implement and evaluate The Embodying Mathematics Project (EMP) between 2015 and 2017). It was funded by *The John Lyon's Charity*, the *Paul Hamlyn Foundation,* and a *SHU Impact Fellowship Grant*.

The project focused on developing drama informed mathematical movement activities for KS2 teachers and children, drawing on previous work by Complicite and other activities developed in mathematical education contexts by teachers, curriculum designers and others.

This document provides a summary report of the project, providing information on the background and rationale, project activities, evaluation and design, project implementation and attitudes to the project, supporting and constraining factors, as well as analysis of outcomes for teachers and pupils. Interpretations and implications are considered. Further detail of evaluation data and examples of activities are provided as appendices. It is also intended that a larger set of project learning materials will be made available for download on a web platform.

2 BACKGROUND AND RATIONALE

Complicite's theatre is rooted in ensemble and physical theatre practices. The company developed a number of ensemble movement mathematics activities which were used by actors as part of the creative process of devising a play - *A Disappearing Number* - centred on celebrated Indian mathematician Ramanujan (see Abbott, 2014). These activities informed workshops for schools offered by the company's Creative Learning arm. In 2015, Complicite invited proposals to develop this work further and members of the Mathematics Education Research Group at Sheffield Hallam University proposed a curriculum and professional development project - the Embodying Mathematics Project (EMP) - focused on primary mathematics for 7-10 year olds.

The EMP was informed by a variety of prior research and mathematics education activity. There is some evidence that engaging in drama can impact positively on pupils' attitudes to school and their mathematical attainment (Fleming, Merrell & Tymms, 2004; Şengün & İskenderoğlua, 2010). Materials to support learning mathematics have been developed that utilise the story telling aspects of drama (Pound & Lee 2015). The interest in the application of drama to mathematical learning can considered part of a growing current in education focused on STEAM (Science, Technology, Engineering, Arts, Mathematics) education, and on arts-based creative pedagogies more generally.

Different emphases are found within the developing STEAM literature and practices with, for example, the arts being viewed as a way of enlivening science and mathematics or with a more holistic view in which the distinctive contribution of the arts reshapes the meaning of mathematics and science activity (Colucci-Gray et al. 2017). The EMP was informed by the latter approach. Further, narrow accountability measures increasingly mean that the arts and arts-based pedagogies are marginalised in the curriculum, so diminishing the quality of education and limiting learners' experiences. Thus, part of the rationale for the project was to demonstrate the value of drama based pedagogies and to create a space for them in an often overloaded curriculum in which 'high stakes' subjects that more directly inform school status are emphasised.

Recently, steps have been taken to conceptualise an ensemble or rehearsal room pedagogy (Kitchen, 2015; Neelands, 2009) in the context of drama education, and specifically in relation to teaching Shakespeare in English schools. There are resonances in the construct of ensemble pedagogy with developments in mathematics education that promote collaborative learning and co-responsibility for each other's learning (see for example, Angier and Povey, 1999, Boaler, 2008; Esmonde, 2009).

Separately, embodiment has gathered much interest in mathematics education both in theory (for example, de Freitas and Sinclair, 210, 2014; Davis, 1995; Lakoff & Núñez, 2000; Radford, 2003; Reid & Mgombelo, 2015; Roth 2010) and also in practice through activities that involve whole-bodied exploration of mathematical concepts (see for example, Wright, 2001). In England the concept of 'people maths' has been promoted (Bloomfield & Vertes, 2005). Watson (2005) proposed the engagement of all senses through a dance-mathematics

pedagogy, and subsequently developed a set of mathematics curriculum materials focused on dance as part of the Bowland Mathematics project[3].

Attention to embodiment in mathematics sits within a more general current interest in the relationship between learning and kinetic movement theoretically (Bautista, Roth, & Thom, 2011; Malinverni & Pares, 2014)) and in practice, for example, through the relationship of dance to the curriculum generally and not just mathematics (Skoning, 2012).

The EMP was informed by these various approaches and explored ways that drama, and specifically ensemble practices and principles, can support mathematical learning through embodied experience to foster engagement and support a sense of learning together. In contrast to Complicite's earlier mathematics and drama workshops (prior to the EMP) in which any professional learning teachers gained by observing Complicite workshops was vicarious. In the EMP teachers rather than (only) theatre practitioners were positioned as leaders of embodied activities, with professional development activities devised to support this.

The project was developed with an awareness that primary mathematics is often decontextualised and lacks meaning. Pupils are increasingly grouped according to perceived mathematical ability and this has implications for social justice as socially and economically disadvantaged children are often negatively impacted by these arrangements (Boylan & Povey, 2009; Povey, 2009, Marks, 2013, 2014). These trends mean that learners can become alienated from mathematics, from other people and ultimately from themselves. In addition, many primary teachers have themselves had alienated experiences of school mathematics and report anxiety about teaching the subject linked to their own negative experiences of mathematics in school and beyond (Bibby, 2002). Thus the EMP was conceived as a means of offering and supporting a different experience of mathematics for pupils (and teachers) than the one that is usually found in schools currently.

[3] http://www.bowlandmaths.org.uk/projects/dancestar.html

3 THE EMBODYING MATHEMATICS PROJECT

3.1 AIMS

The project sought to:

- design, develop and evaluate curriculum materials, activities and pedagogy informed by movement based and ensemble practices
- develop appropriate professional development activities
- examine how teachers can mediate embodied and ensemble learning to impact on pupil learning and attitudes
- identify appropriate evaluation methodologies and tools for assessing outcomes of embodied activities
- assess outcomes for teachers of engagement in professional development
- and assess learning and social outcomes for pupils.

3.2 OVERVIEW

The project overall consisted of three projects that were mutually supportive but implemented as distinct activities:

- Year 1 2015/16 - London 4 schools, 8 teachers - Complicite and SHU co-design and implementation, SHU evaluation
- Year 2 2016/17 - Sheffield 2 schools, 6 teachers - Complicite and SHU design, Complicite implementation, SHU evaluation
- Year 2 2016/17 - London 6 schools, 10 teachers - Complicite design and implementation, SHU evaluation

Details of the different activities used in the three sub-projects are provided in summary form in Section 3.4. Some 24 different teachers and 21 classes took part (taking into account teachers who participated for more than one year). Approximately 600-700 pupils in total directly experienced the project including participating in at least one workshop with a Complicite practitioner.

3.3 COMMON FEATURES

In this section, common aspects of all three projects are described.

3.3.1 Team and roles

As noted in Section 3.1, during the project the two main partners, Complicite and SHU, had shifting roles with Complicite taking more responsibility for design and implementation during the project.

Complicite

Project Manager: *Poppy Keeling*

Creative lead*: Victoria Gould*

Complicite Associates and workshop leaders: *Victoria Gould and Shane Shambhu*

Project Coordinator: *Dina Mousawi*

Sheffield Hallam University

Project Lead and Principal Investigator: *Professor Mark Boylan*

Curriculum development lead: *Professor Hilary Povey*

Members of the evaluation team: Sarah Reaney-Woods, Gill Adams, Ben Willis, Judith Higginson

St Marylebone School, London/West London Maths Hub

Professional development lead: *Nick McIvor*

3.3.2 Programme components

3.3.2.1 Complicite Workshops

Led by Complicite practitioners, in London in 2015/16 (Year 1) workshops spanned two hours (the length Complicite used prior to the project), with the main focus of the workshop being on pupils' experience with teachers observing. In Sheffield and London in 2016/17 workshops were designed to last an hour. In Sheffield, the aim of the workshops was more fully on being a professional development opportunity for teachers to witness and learn from practitioners using embodied activities with pupils. Further, in some cases in Sheffield activities were co-led by teachers and practitioners. Similarly, in London in 2016/17 the main aim of the workshops was for teachers to learn from observation.

3.3.2.2 Lesson activities

Lessons were designed to be used either inside or outside the classroom. Appendices 1 and 3 provide a summary of lesson activities and content. Lessons consisted of a number of activities, with teachers free to select from these, given a recognition that all of the activities included in a 'lesson' might take longer than a single hour. In London 2015/16 (Year 1), lesson activities complemented Complicite workshop activities rather than reproducing them. They were also designed to be used flexibly across KS2. In Sheffield 2016/17, workshop activities were integrated into lesson plans, thus workshops consisted of demonstrations of lesson activities. The focus was on Y3. In Sheffield, *Being a Mathematician* (see below), teaching prompts and notes on mathematical concepts were integrated into lesson and activity descriptions. This change to presentation of materials response to teacher feedback in Year 1. Appendix 2 and 4 give examples of lessons from Year 1 and Year 2 respectively.

3.3.2.3 Group Mastery Activities

Group Mastery Activities (GMAs) were developed for the second year of the project (see Appendix 5 for how these were presented to teachers in London 2016/17). The GMAs were developed with the aim of reproducing aspects of ensemble activities from Complicite workshops which had originally been designed to be done in a large, open (ie non-

classroom) space within a classroom setting. Further, the aim of a GMA is that everyone has a sense of mastering both a physical activity and mathematical learning together. GMAs also offered the opportunity to develop a 'felt sense' of number. They were designed to be done in the classroom regularly, ideally three times a week. GMAs consisted of a physical 'root' to which mathematics layers were added. GMAs have resonances with unison response that is part of a number of learning traditions internationally (see Watson, 2002).

3.3.2.4 Being a Mathematician

This was a strand of the project used in London in Year 1 that was informed by evidence on the power of metacognition in mathematics learning. 'Being a Mathematician' aimed to promote a set of dispositions that embodied and ensemble activities could potentially cultivate and ones for which there was evidence from meta-cognitive interventions of association with improved mathematical attainment and relationships to mathematics (see Appendix 6). A number of drama based activities were provided. A revised version of the 'Being a Mathematician' dispositions, informed by teacher and team reflections, was shared with teachers in in Sheffield in 2016/17, but was not emphasised or addressed in PD after the introductory day.

3.3.2.5 Professional development activities

As well as practitioner workshops in schools, a variety of patterns of CPD days and twilight sessions were used to support professional development. CPD day activities emphasised teachers experiencing embodied and ensemble activities as participants. Consequently, typically CPD would consist of project team members leading EMP lesson activities or GMAs, followed by reflection on the experience and discussion of use with pupils. Twilight sessions tended to focus on reflection on use of materials. The CPD days were called 'development days' to indicate that although professional development was an important focus, teachers were also supporting the development of materials and activities.

3.3.2.6 Performance

In both Sheffield 2016/17 and London 2016/17, the use of GMAs led to a mathematical 'performance' to other pupils and/or to parents. Performances were not designed primarily to entertain, but rather to make the mathematics children had engaged in public and shared with others.

3.4 SUMMARY OF EVOLUTION OF THE PROJECT

The EMP was conceived as an opportunity to explore the possibilities for, and constraints on, drama informed mathematics pedagogy and professional development. Thus, as anticipated, project activities evolved over the two years.

In the first year of the project, teachers were invited to participate from across Key Stage 2, and consequently lesson activities were developed that could be used flexibly across Y3, Y4 and Y5 year groups. Consequently materials covered a wide range of content. In the second year of the project two parallel developments from the first year were explored. Firstly, in Sheffield the project continued to combine lesson activities with the newly developed GMAs, focusing only on Y3 pupils. In London in 2016/17, conversely, pupils from across

Years 3 to 5 continued to be involved but with a focus mainly on GMAs with a small number of supporting lesson activities. This represented an evolution from 'embodied mathematics' to a greater emphasis on 'ensemble mathematics'. A further important difference in London in 2016/17 is that the project took place over a single school term.

3.5 PARTICIPATION AND ACTIVITY

The table below provides a summary of participation and activity across the three projects.

Table 3.5 Summary of participation and activity

Element	London 2015/16	Sheffield 2016/17	London 2017
Number of schools	4	2	6
Number of teachers & classes	8 teachers, 8 classes	6 teachers, 5 classes	10 teachers, 10 classes
Year groups	Y3, Y4, Y5	Y3	Y3, Y4, Y5
Length	Two terms (with intro the previous term	Three terms (with intro the previous term)	One term
Curriculum activities	4 modules - 20 lessons[4]	5 modules - 20 lessons	Set of activities for approximately two introductory lessons, plus GMAs
Location of activities	Half inside the classroom, half in other spaces	Half lessons inside the classroom, half in other spaces	Introductory activities and performance in other spaces, GMAs in classroom
Mathematical content	Number patterns, multiples, factors, inverses, simple functions, loci, angle, shape property, symmetry,	Number patterns, multiples, factors, inverses, simple functions, loci, angle, shape property, symmetry, place value, fractions	Multiples and factors
Professional development	2.5 days, 4 half term twilights	4 days, 3 twilights	1 day, 1 twilight
Practitioner workshops in schools per class x 1 hour	2	3 (1 focused on performance)	2 (1 focused on performance)
Being a Mathematician	Yes	Provided but not promoted	No
Performance	No	Yes	Yes

[4] A lesson might take more than a timetabled lesson depending on teacher choice of activities. If all materials were used then 20 lessons might be 40 hours of curriculum time.

4 RESEARCH AND EVALUATION

4.1 METHODOLOGY

A design evaluation was undertaken to inform development of activities during the project as well as potential future development. Although outcomes were assessed the main purpose here was informative rather than evaluative given the atypical nature of schools' participating and that activities were being piloted.

The evaluation used a mixed-methods approach with data gathered from:

- notes and audio recordingsfrom design and project meetings
- notes and audio recordings from professional development events
- reflections by project team members
- observations of workshops
- teacher records of use of materials and reflections on materials
- interviews with Complicite practitioners
- interviews with teachers (2 in London 2015/16 by telephone, 5 in Sheffield 2016/17 by SHU researchers face to face)
- Short video segments recorded by Complicite with London 2016/17 teachers
- survey of London 2016/17 teachers
- review half day with London teachers
- review half day with Sheffield teachers to discuss preliminary evaluation outcomes
- four focus group interviews with a total of approximately twenty Sheffield pupils
- pupil attitude surveys
- a pre and post-test of mathematics related to GMAs.

Qualitative data was analysed using thematic analysis and quantitative data analysed using standard and recognised statistical methods, with details given when data is reported or in appendices as appropriate. Data entry for the London 2016/17 project was undertaken by an administrator employed directly by Complicite and for Sheffield 2016/17 by an SHU administrator. Quantitative analysis was undertaken by an SHU Research Fellow who was independent of the design team. Thus, data entry and analysis have a degree of independence from the immediate project team.

4.2 ETHICS

The research was conducted in accordance with SHU and the British Educational Research Association guidelines. Schools recruited to the project were sent detailed information on project activities, data protection and potential use of data and headteachers and teacher participants signed a memorandum of understanding prior to joining the project. Individual consent was sought and obtained for teacher interviews. Parental opt out consent was sought for the multiple and factors test and the Pupil Attitude Survey and signed parental

opt in consent obtained for participation in focus group interviews, with pupils' personal consent audio recorded.

4.3 OUTCOME MEASURES

4.3.1 Pupil Attitude Survey

A pupil attitude survey (PAS) was an important instrument for evaluation in both London and Sheffield. The PAS was adapted from one used in another study (see Boylan et al., 2016) which in turn was informed by previously developed scales. The PAS was trialled in the EMP during 2015 in London, further developed and then used as a pre- and post-test in both London and Sheffield during 2016/17. See Appendix 8 for the final survey. Because of the age of the children participating, it was administered by teachers reading out the questions, and pupils' individually completing the survey. The Likert questions in the PAS related to two factors: mathematics affect (attitudes to mathematics) and working with others in mathematics. To allow for comparison with a previous cohort, the previous Year 3 cohort (Year 2 2015/16) also took the PAS. In addition, as part of the post-test survey, questions were asked about attitude to project activities with the London and Sheffield surveys varying slightly due to the different project activities.

4.3.2 Multiples and multiplication facts test

A short test of knowledge of multiples and multiplication facts related to GMAs was devised and used as a pre and post-test in Sheffield 2016/17. In addition, the test was administered to the previous Sheffield cohort (2015/16) to provide a comparison group. See Appendix 9.

5 IMPLEMENTATION AND ATTITUDES TO THE PROJECT AND ACTIVITIES

5.1 IMPLEMENTATION AND TEACHERS' ATTITUDES

In both interviews and surveys, teachers, in general, indicated positive attitudes to the project, particularly in the second year in both Sheffield and London.

Two of four schools in London involved in the first year chose to continue with the project, further evidencing that the project was seen as worthwhile by those teachers. In this section teacher attitudes to specific aspects of the project are reported.

5.1.1 Balance of activities and implementation

In London 2015/16, a number of teachers noted difficulties in accessing spaces outside the classroom. Consequently, in 2016/17 the number of activities designed for use outside the classroom was limited, and GMAs were developed to provide ensemble experiences in the classroom. However, teachers in Sheffield 2016/17 also reported adapting activities designed to be used in large spaces within their classroom by moving furniture and having some pupils do the activity and some watch, for example 'walking the space' in the classroom.

Teachers in all three sub-projects reported using materials flexibly and, in the case of lesson activities, selecting some activities from a 'lesson' and developing their own lesson from these.

Due to current focus in primary mathematics on number, number activities were found to be easier to fit into the curriculum and other activities on shape and space felt to be more useful as additional or supplementary activities.

5.1.2 Workshops

Teachers valued workshops as professional development activities, with London (2016/17) teachers ranking this as one of the top three aspects of the project in relation to PD. Teachers valued observing and learning from practitioners working with pupils and this helped to remind or reinforce learning from development days.

In Sheffield, two teachers specifically mentioned the value in being able to ask for advice, and one spoke about later workshops as being like "team teaching" (Sheffield teacher 5).

One teacher (Sheffield teacher 3), reflected that visits to schools could have been used for greater professional learning if practitioners could stay after workshops to reflect with project teachers.

5.1.3 Being a Mathematician

In London 2015/16 , in interviews, the conceptual framework provided by the Being a Mathematician strand was broadly welcomed by teachers. One school developed this as a whole school approach and,after the second year of involvement in the project, reported that they found the first year more impactful on their practice than the second year, partly

because of this strand. The Being a Mathematician framework was refined based on application by teachers in London during 2015/16.

5.1.4 Group Mastery Activities

GMAs were viewed positively by both London (2016/17) and Sheffield (2016/17) teachers. A number noted that these were the project activities they were most likely to use in the future. GMAs were not necessarily seen as a better way of exploring mathematical content, but rather:

> supplemented the work we did in class and gave children a really effective way to understand mathematical concepts and ideas they often struggle with when we're just using concrete materials and more abstract concepts in class. (Sheffield Teacher 3)

At the same time, teachers in Sheffield reported they tended to use GMAs less as time went on, stating that it was difficult to sustain momentum and that pupil enthusiasm lessened over time. The activities were seen as particularly valuable at the start of the year. Teachers of Y3 pupils, in both Sheffield and London, commented on the appropriateness of the mathematical activities or, alternatively, that children grasped the mathematics easily. A teacher of Y5 pupils in London stated that the GMAs' mathematical content was not challenging enough for their pupils but more suitable for younger children.

Teachers reported that pupils found embodied aspects of GMAs challenging initially, with 6 out of 8 London 2016/17 teachers agreeing or strongly agreeing that pupils found them hard. 'Embodied aspects' of GMAs refers to the combination of physical activity and social-psychological aspects as well as embodying mathematical thinking. This contrasts with the challenge of the mathematical content abstracted from the GMAs.

As one Y3 teacher put it, acting as 'the perfect ensemble ' was something for pupils to aspire to and there was value in trying to perfect a GMA even if this was not achieved. The same teacher commented:

> I don't think we ever had a session where there wasn't somebody that forgot to do something…..but they picked up that [the what the ensemble aim was] fairly quickly (London 2016/17 teacher 1)

Engaging with GMAs (and other ensemble embodied activities) required the development of some children's' embodied and social capacities. One teacher reported:

> A huge amount of time and effort went into just getting the children ready to be able to engage with these sorts of activities (Sheffield Teacher 3)

Sheffield teachers shared strategies they used to develop pupils' capacity to engage with GMAs. One teacher's approach was to create opportunities for pupils to observe each other doing GMAs and to reflect on the experience. In the following quote they share an example of this related to using GMAs (see page 61-63 for a description of the activity :

> [We've discussed] it's really important that everyone understands and we give everyone time to get the right answer …. for example, [we've discussed what happens

> when] we've done ‘everybody stand up together when I say a multiple of 3’.when I say a list of numbers in turn. For example We've discussed, "what we should do if I say ‘12’, and you know straight away that 12 is a multiple of 3". I have said, "that's great but I want you to wait until you think everybody knows that and has time to know that, so you can all stand together".

Teachers reported the perseverance needed to master GMAs as a whole class as leading to valuable learning (discussed in Section 7).

The last example was related to developing a sense of ensemble by giving others time to be able to include themselves in the activity. A related example was addressing informal patterns of social inclusion and exclusion within the class. A London teacher discussed using the GMA 'loop activity' (see pages 61-64). In the loop activity a virtual loop or set of connections is set up in the class by 'passing' being the lead person from one pupil to another. Passing is done by eye contact. One someone has been the least person they then pass this on. Eventually, the loop closes as the last person passes the leadership back to the first person.

The teacher noted she had to offer some guidelines to the class about not passing the loop to your friends and had to personally be part of the loop to ensure one child who was often isolated in the class was included (London, 2016/17 teacher 1). Both of the last two examples of teacher practice point to the way in which GMAs helped to promote a sense of togetherness in classes or at least opportunities for discussion of relationships and social learning. Discussion about this was an important aspect of implementation. The value of GMAs in this regard is discussed more fully in Section 8.

The short length of GMAs was viewed positively, and allowed them to be used when there was a period of time between other activities:

> I could just use them as and when: in the middle of the day; at the start of the lesson; end of the lesson; as an activity to get children re-focused on something. Different GMAs lend themselves to different classroom strategies. So re-focusing the children could just be the ‘arms up’. Whereas a starter could be counting in multiples or things (Sheffield 2016/17, teacher 4)

Similarly, the flexibility of being able to adapt or develop GMAs was valued.

The majority of London teachers (2016/17) had used, or would use, GMAs in other subject areas. A Sheffield teacher described using a GMA to count in Spanish and another using them at the start of Circle Time.

Most London teachers reported using GMAs two to three times per week. In Sheffield, their use varied from once to three times per week overall, and with their use being less later in the year than at the start. For example one teacher reported using them nearly every day at the start of the year but later in the year once per week.

5.1.5 Lesson activities

Teachers interviewed in Sheffield (2016/17) were positive about lesson activities both in relation to mathematical learning and to pupil engagement. As noted above, number activities were easier to integrate into schools' curricula. Place value and fraction activities were most frequently named when asked which lesson activities might be used in future years.

Teachers in both Sheffield schools stated that the symmetry and shape activities did not fit with the schools' interpretations of the KS2 mathematics curriculum for Y3. Two Sheffield teachers also noted that, with the some of the symmetry activities, Y3 children found it difficult to be accurate with their physical positioning or to stay till enough to represent the mathematical content. This then required a lot of intervention from the teacher and so reduced children's autonomy.

Sheffield teachers appreciated the overall presentation of activities, particularly if understood as a set of related activities rather than a lesson, with instructions being "very clear and you can read it before the lesson and know what you want to do without having to keep picking it up and rereading it" (Sheffield teacher 1). Another teacher summarised this as materials being "very easy to follow" (Sheffield teacher 5).

5.1.6 Professional development activities

In general, teachers in all three sub-projects considered the amount of professional development appropriate (see Appendix 8 for details on London teachers' views). When London teachers were asked about the value of different types of experiences, the full development days were seen as most beneficial. Teachers in the second year of the project in Sheffield saw less value in twilights, particularly later in the year when opportunities for reflection were offered rather than additional content. The professional development focused on performance was reported as leading to confusion.

Activities that were most valued during development days were opportunities to engage in the activities as participants, though one teacher stated that talking to other teachers about how they used the materials was most useful. Teachers also valued observing practitioners working with children.

One teacher suggested that observing colleagues as well as practitioners could have created further professional development opportunities.

5.1.7 Performance

Teachers interviewed were positive about the performance, though one wondered whether having parents doing activities rather than watching might be more powerful in terms of parents understanding what was involved. One reported a parent concerned that the mathematical level was not challenging enough.

5.2 PUPILS' ATTITUDES

5.2.1 Teacher perceptions

Overall, interviewed teachers reported pupils being positive about the project. Even though GMAs were found to be challenging, completing a GMA successfully together was satisfying. For example, above it was noted that one teacher had adapted a GMA to count in Spanish; managing to complete a 'loop' on this occasion was noted as source of pride by the pupils.

A number of teachers pointed to different relationships that children had to the activities. One reported that their whole class "bought into it really easily" (Sheffield teacher 5), whilst others had minorities of pupils who were resistant to or disengaged from GMAs. In some classes, this appeared connected to pupils' prior attainment with high attaining pupils less like to engage fully. However, this was not true of all high attaining pupils. Teachers in Sheffield also reported that, as time went on, when using the GMAs, there was a sense of boredom for some pupils and some finding it challenging to maintain engagement and enthusiasm over time. However, this was not reported in London in 2016/17 and the difference may be due to the Sheffield project spanning three terms rather than one term in London.

One teacher noted a relationship between engagement and gender, with boys tending to be the pupils who found it more difficult to "channel their liveliness into the work that we've been doing together" (Sheffield teacher 3).

5.2.2 Survey

5.2.2.1 Attitudes to the project

In both London and Sheffield, pupils were positive about the project overall, as shown in the tables below and with more detail provided in Appendix 11. The tables below summarise pupil responses through scoring Likert responses 1-5: for statements positive about project components or activities, 'strongly agree' scored 5, but for items that are negative about project activities, 'strongly disagree' scored 1. A mean score is used as a proxy [5]. This means that the high score in each case represents higher positive attitude to the project.

[5] Note that scoring Likert scales in this way makes assumptions about the responses as ordered data and with differences between items as being of the same magnitude. However, for the purposes of providing a single proxy statistic for the data in Appendix 11, the mean score is used as a convenient tool.

Table 5.2.2.1a London 2016/17 Pupils' attitudes to the project

Statement	Mean	Interpretation
I enjoyed going outside the classroom to do maths activities	4.2	Between agree and strongly agree
I did not like maths lessons where we did movement and maths together	2.3	Between disagree and neither disagree nor agree
I liked doing the maths performance	3.5	Between neither disagree or agree and agree
I got nervous in the maths lessons outside the classroom	2.1	Between disagree and neither disagree or agree (close to disagreeing on average)
I did not like the activities in the classroom when we all did movements at the same time	2,3	Between disagree and neither disagree or agree (close to disagreeing on average)
I liked it when Victoria and Shane did movement maths with us	3.8	Between neither disagree or agree (close to agree)

Table 8.2.2.1b Sheffield 2016/17 Attitudes to the project

Statement	Mean score	Interpretation
I enjoyed going outside the classroom to do maths activities	4.2	Between agree and strongly agree
I did not like maths lessons where we did movement and maths together	2.1	Between disagree and neither disagree nor agree
I liked doing the maths performance	4.0	Agree
I got nervous in the maths lessons outside the classroom	2.0	Disagree
I liked it when different teachers did movement maths with us	4.1	Between agree and strongly agree

The tables indicate an overall positive attitude to the project. However, it is important to note that this was not shared by all pupils, with between 5-33% on each item indicating a negative attitude, and a further 11-25% neither agreeing nor disagreeing.

Analysis of London attitudes showed that 5 of the 6 questions formed a factor, that is there were patterns in the pupils' responses, thus indicating that pupils had similar attitudes about different aspects of the project. One statement 'I was nervous in maths lessons outside the classroom' did not fit into this pattern (see Appendix 12).

5.2.3 Focus groups

A total of four focus groups were carried out in the Sheffield schools - two at each school - involving 22 pupils. Class teachers asked for volunteers to participate and in addition pupils' parents returned consent slips. Thus, the sample is not representative of all pupils in the classes. However, across the four focus groups, pupils participated who reflect the different type of views expressed about the project in the Pupil Attitude Survey. Further the balance

of different attitudes to the project was in similar proportions to the report in the survey, with most pupils in two of four focus groups being broadly positive about the project, pupils in the third expressing mixed views, and the fourth having overall negative attitudes.

Pupils who were positive about the project stated that they enjoyed working in a circle, and liked that everyone had a chance to do something. They enjoyed exploratory aspects of workshops:

> Pupil 1: they asked what we could do to make it better. If we get it wrong, they'll spot it but they'll let us try and figure it out first, so we have chance to say 'oh we got something wrong' and we'll figure it out and change it.
>
> Pupil 2: They didn't just tell us how we could improve, they let us participate and try and find out what the answer was.
>
> Pupil 3: they didn't just go 'ooh, you've got to hurry up'. They let us take our time.

However, for others, workshops were experienced differently, with children reporting that sometimes they felt they were 'proved wrong' and this made them feel uncomfortable.

For some working outside the classroom in the circle caused some anxiety:

> Pupil 5: Worried because you didn't know what you were going to do

Another echoed this comment, stating they were discomforted by "not knowing what was happening". For others there was physical discomfort from "standing around two long"[6].

There was evidence that many pupils had internalised messages about working together in relation to GMAs. Many pupils described the activities as fun, helpful for maths, promoting awareness and working as part of a team, and that everyone had a chance to participate. A recurrent theme for some was that it was ok to make mistakes.

One pupil reported:

> Pupil 5: When we were doing it people said it felt magical. That was the first time we did it but now it just feels normal.

Pupils enjoyed the performance ,though for some there was anxiety. Meeting with children from the other was a highlight and working as a team in the performance was spoken of with pride. Conversely, another said it was boring because:

> Pupil 6: At points other people were doing stuff and you didn't know what they were doing. We enjoyed when they got into different groups 'one group of four, two groups of four'.

[6] One adaptation made was for pupils to sit between activities outside the classroom or do some activities, such as clapping, sitting down.

One focus group consisted of high attaining pupils (as described by their class teacher) who were more negative about the project as a whole. In contrast with the other pupils, this group of eight pupils drawn from a single class stated they did not like the lessons or workshops after the first one. Their preference was for individual work. Whilst these pupils did not 'buy into' the ensemble concept of working together, it is also important to note that they did not feel particularly mathematically challenged by the activities.

6 CONSTRAINTS, ADAPTATIONS, AND SUPPORTING FACTORS

In this section, constraints and adaptations to overcome the constraints, and supporting factors relevant to implementation are considered.

6.1.1.1 Constraints and adaptations

Curriculum and time pressures

Teachers reported that it was challenging to make time for activities given "the full-on-ness of your school agenda"(London teacher, Y3, 2016/17)

An important issue for teachers was the fit between project activities and the school curriculum. Currently, the emphasis on number in the primary curriculum means that number activities are more likely to be used by teachers. Where curricula diverged, the project activities became something that needed to be 'fitted in' rather than the more 'seamless' relationship described as happening in the autumn term.

Spaces outside the classroom

The availability of spaces outside the classroom limited what teachers could do. As a design feature, the project team had limited the number of outside lessons. However, this was still an issue. One creative solution to issues of space was to revisit activities at the start of PE lessons (Sheffield teacher 2016/17).

Pupil concentration

Teachers highlighted issues of concentration span, both in terms of standing still in a circle or length of activities as a whole. For Y3 pupils a full lesson outside the classroom using EMP activities was felt to be a long time for some classes and children. Working outside the classroom for 20-30 minutes was found to be a more beneficial time by one Y3 teacher pointing to a 40 minute limit on concentration span, with the teacher suggesting that embodied activities could be interspersed with activities using different learning modes - such as individual whiteboards or other written activity.

Accountability pressures

Teachers in one of the London schools in Year 1 found it challenging to implement the project due to the circumstances of their school which was under accountability pressures. This school did not continue with the project into the second year.

6.1.1.2 Supporting factors

Flexible classroom spaces

One Sheffield school had folding desks with wheels designed to be quickly rearranged and to clear spaces in the classroom. This facilitated adapting the ‘walking the space' activity in the classroom and using an inner circle of children engaged in an activity in the classroom and an outer circle of observers.

School orientations and developments

One of the Sheffield schools was engaging with mastery principles, including an emphasis on pupils working together, as well as ‘concrete, pictorial, abstract’ as a teaching sequence and so engaging in the project was supported by current developments in the school. In the other Sheffield school there was, similarly, an emphasis on the use of concrete materials and experiences in mathematics.

A teacher in one of the Sheffield schools noted that they were fortunate to have a leadership team that supported teacher creativity, experimentation and engagement in research. They were not sure that other schools would be as supportive to working in new ways. The teachers themselves worked in a culture of teacher enquiry through lesson study embedded into the schools' practice. Further, the project fitted with the schools' approach of "getting the children doing rather than sitting” (Sheffield Teacher 4). Concurrently with the EMP, the same school was engaged in developing mathematics lessons linked to PE activities to promote pupil physical activity.

As well as pedagogical orientation, in both Sheffield schools mathematics was usually taught in all attainment groups.

Teacher capacity

In one Sheffield school, one teacher had a background in music and the other had completed a teacher enquiry project. Similarly, in London teachers attracted to the project had an interest in creative learning approaches. One had a background in drama and reported that their school emphasised oral ways of working and used the language of 'teams'. Thus, it is important to recognise that the teachers and schools involved in the project were not typical and this may be an important issue to consider in replication of the project.

As noted earlier, teachers in Sheffield reported expending significant effort engaging pupils with GMAs and other ensemble movement activities, involving being advocates for and teachers of collaboration. The commitment of teachers to this way of working is likely to be important to successful implementation in other schools.

7 PROFESSIONAL DEVELOPMENT OUTCOMES

7.1 OVERVIEW OF PROFESSIONAL DEVELOPMENT

London teachers (2016/17) were surveyed about professional development outcomes. Teachers strongly agreed or agreed that the project had led to the following outcomes (number of teachers out of 8 who completed the survey in brackets):

- My understanding of ways to teach one or more areas of mathematics has increased (8)
- I know more about how to link mathematics and movement activities (8)
- My ability to teach mathematics outside the classroom has increased (8)
- I am more confident to lead mathematics outside the classroom (7)
- I am more able to turn mathematics into something to be shared through performance (7)
- I am have more strategies to develop a sense of a learning community in the classroom (6)
- My idea of what mathematics is has changed through taking part in the project (4)

Interviews with Sheffield teachers indicated similar professional learning outcomes and provided further insight into their learning.

7.2 COLLABORATIVE LEARNING

One teacher commented:

> It's been interesting to think about how they work together when they work in a group and whether they are thinking about making sure everyone in the group understands or whether they are just kind of saying 'oh I get it so I'll do it, if they don't understand, then that's fine'. (Y3 Teacher Sheffield 2016/17)

The extent to which teachers' views on collaborative learning in mathematics had changed depended, not surprisingly, on their starting points. For some teachers collaborative learning was already established in their practice, and these teachers reported this being deepened, particularly in terms of the whole class working together building on pair and group work.

7.3 VIEW OF MATHEMATICAL 'ABILITY' AND MATHEMATICAL ACTIVITY

One teacher (London 2016/17 teacher 4) who had participated across the project over two years saw links between developing a sense in the class of responsibility for others' learning and moving away from more fixed views of mathematical 'ability'. These were key messages of EMP professional development activities.

One teacher who had taken part in both years of the project referred back to the Being a Mathematician strand:

> I think the great thing is that we've had a lot of space to think about what being a good mathematician [is] …., it's actually made me think in a broader sense about what I want my maths lessons to look like, or if I was a leader what I would want maths to be like in my school, and how I would want children to think about maths…. The practical activities are great as well, and that's great to have that in your bank of knowledge, that the great thing is your changing, my changing mindset – and what that can do for what you perceive as a good maths lesson or what you perceive as good maths teaching (London teacher 2016/17, teacher 5).

This teacher reported changing seating arrangements in their classroom from 'ability' groups to mixed ability tables. The same teacher reported a significant change in her capacity to notice what was happening in the classroom.

7.4 Extending the teaching repertoire

Teachers told us that engaging in the project had led them to extend their repertoire of teaching approaches. There were two particular aspects to this.

One related to embodied and movement approaches to learning mathematics, with two of the eight Sheffield teachers who were, from their self-reports, the most sceptical at the start of their involvement, expressing surprise that this combination worked well. The second related to the pedagogical approach in the learning activities, summarised by teachers as 'open', or"showing a concept to children rather than just telling them" (Sheffield 2016/17 Teacher 1). The extent to whether this teaching approach was novel varied across the teachers and their current practice, and consequently the degree of learning varied.

7.5 Teacher agency

In both London (2016/17) and Sheffield (2016/17) teachers reported and welcomed an agentic relationship to materials. A London teacher who had been part of the project for two years referred to taking ownership (London teacher 2016/27 teacher 4). In Sheffield a teacher described (Sheffield teacher 4) adapting a fractions lesson activity to use crash mats as sites for forming fractions. Other adaptations have been discussed above.

7.6 Subject knowledge and pedagogical subject knowledge

In London 2015/16, the teachers participating varied in the depth of their mathematical subject knowledge. Project team members observed some misconceptions being addressed and a sense of a deeper understanding of relevant mathematical structures developing.

8 PUPIL OUTCOMES

8.1 ATTITUDES AND SOCIAL LEARNING

8.1.1 Teacher perceptions

8.1.1.1 Togetherness

London 2016/17 teachers, via the survey, reported (number in brackets is how many responded out of eight):

- The group mastery activities helped develop a sense of togetherness (7)

One teacher who had participated in both years of the London project:

> I think one of the most poignant and important things is the sense of togetherness that we've got in doing this and the sense that there is no longer, I think, a good place and a bad place in the maths classroom. I think now it's more a case of… when we do these group mastery activities, particularly, we're all in this together and we're all going to help each other out (London 2016/17,Teacher 4)

The same teacher linked this to breaking down a pattern of children labelling themselves or each other as good or bad at mathematics. The benefits of this were summarised by one teacher in the following way:

> You have so many different learners with different needs [in a class] that this project really allowed everyone to shine. It allowed the children to learn from each other, to grow, to feel confident and to feel a part of something (London 2016/17, Teacher 3).

Similarly, another teacher emphasised the value of ensemble activities for children with SEN or EAL needs and feeling part of a community in the classroom (Sheffield teacher 4). One teacher described the value in being able to give attention to the whole class at once and this being rare in primary classrooms. She linked this to improved relationships with the children and value for the children to feel:

> She's [the teacher] giving her attention to all of us because we together are creating something special (London, 2016/17 teacher 4).

Thus, the GMAs were considered to have a purpose beyond mathematics as the same teacher went onto say:

> I think that process has really paid dividends in terms of bringing them together as a unit, as an ensemble and getting them understanding how to work together with each other and also to understand the benefits of working together and supporting each other (London, 2016/17 teacher 1).

8.1.1.2 Social learning and regulation

Two teachers in Sheffield specifically linked the EMP to PSHE as did one in London. Teachers reported using GMAs for social purposes, for example to calm children or to recreate a

sense of unity when there was disharmony in the class. Others described using activities at different points in the day (London 2016/17, teacher 2). Although the social and mathematical learning aspects of GMAs were usually discussed separately, one teacher encouraged pupils to 'help each other out' where needed.

8.1.1.3 Individual relationships to collaborating

As discussed earlier, teachers reported that not all pupils were positive,with particular mention of initial uncertainty or reluctance'. One reported that pupils engaged move over timeand that there had been "dramatic" changes in attitude: "they have gone from just completely wanting to spoil it and not being interested to wanting to be part of it".

As noted above, this teacher reported spending time discussing the reasons for working in this way. Pupils became more willing to work with others. Although learning to work in ensemble ways was challenging, it was felt that for those pupils who found it hard the project had "led to the development of some really positive learning behaviours" (Sheffield teacher 3).

Although pupils' found GMAs challenging, teachers reported that their use had beneficial outcomes. This was particularly the case in relation to working together.

> It's been a good thing to be pushing the kids to work together and it is important because for it to work, we all need to do it properly and together. They struggled with that a bit at the beginning. We've got a lot of very outspoken characters in my class who want to get a laugh out of everybody. They want to be the centre of attention. They found it quite hard to start with, to tone that down and actually think, right we all need to be doing this together at the same time (Y3 Sheffield teacher 1).

Anecdotes of individual change in attitudes were described by teachers, for example:

> There are children - very vulnerable children - in the class who struggle enormously with these [group/collaboration] sorts of skills and aptitudes. It has been challenging for them at times, but also [we are] seeing them coming on a journey (Sheffield teacher 3).

8.1.2 Pupil survey data

Pupils' pre- and post-test affect and relationships to groups were analysed. In London, no significant change were found. However in Sheffield an overall improvement was found. Appendix 13 gives full statistics of the analysis. However, a more accessible way of understanding the difference is that, for those pupils where there is both pre and post test data, 31 pupils had a higher Pre Affect score than Post, 44 pupils had a lower Pre Affect score than Post (i.e. improvement), and 2 pupils stayed the same. So 13 more pupils had an increase than a decrease, 32 pupils had higher Pre working with others score than post, 43 had a lower pre than post so 11 more had an increase than decrease. Note that there is considerable 'churn' in terms of the measures and this was also found in London.

As noted earlier, an important limitation of the evaluation is that both Sheffield schools are Junior schools. These pupils experience a change of schools and so it may be that attitudes to mathematics change anyway. Comparison of Sheffield 2016/17 Y3 pupils' summer attitudes with that of 2015/16 pupils shows no significant differences.

However we do not know what the comparison (2015/16) cohorts' attitude was at the start of the year and so firm conclusions cannot be drawn. It may be that in these two schools there is a strong emphasis on working together as a whole outside of the project and both already use all-attainment teaching approaches in the project.

In London schools there was a weak correlation between pupils' mathematics affect (post-test) and their liking for the project – pupils who tended to like mathematics tended to like the project. One conjecture at the start of the project was that embodied ways of working might appeal to pupils who did not like usual ways of learning mathematics. However, the data from London does not provide evidence for this. Conversely in Sheffield (2016/17) there was no correlation found between pupils' attitudes to the project and their overall mathematics affect, attitudes to working in groups or to their test scores. The latter finding suggests that whilst a minority of high attaining pupils in some classes were more vocal about negative attitudes, these were not exclusive to them (see Appendix 14 for more details).

8.2 MATHEMATICAL LEARNING

8.2.1 Teacher perceptions of learning

London 2016/17 teachers, via the survey, reported (number in brackets is how many responded out of eight):

- the group mastery activities were effective in helping my pupils learn mathematics (6)

GMAs were valued for:

> the way in which they supported children to pick up on an understanding of pattern, of multiples, of being able to visualise what number means in a very bodily way ….on an anecdotal level this has really helped a lot of these children ….have a good grasp of certain areas of the curriculum particularly to do with number and place value and multiplication (Sheffield teacher 3).

One teacher suggested that GMAs had different benefits for different groups of pupils:

> I think for some of them it's encouraged them to ask more questions and to say 'what if?' I think for the lowest attainers it's helped them with securing their number facts and thinking about patterns (London 2016/17, teacher 2).

GMAs, it was suggested by the same teacher, were a more fluid way of learning number facts than simple memorisation.

A number of teachers offered examples of individual pupils having moments of mathematical insights during activities, for example, realising a relationship between times tables and counting in a multiple, with teachers reporting that seeing and feeling patterns in numbers aided understanding. With regard to these individual events, however, it is important to recognise that pupils may have had similar insights through other types of mathematical experience. Nevertheless, it may be that the ensemble or whole class situation makes misunderstanding more visible.

> At the very beginning of the project we were doing the GMA where you have to raise your hand on different multiples. A boy turned to my teaching assistant and said "what is going on?" And he said "I don't understand how everybody else knows what to do, because I don't". And she said "Why? Why do you think you don't know?". And he said "I guess I just don't know my tables very well." And then he said "I think I'm going to need to learn them otherwise next time I'm not going to know what to do again". (London 2016/17 Teacher 2)

8.2.2 Mathematics tests

In Sheffield a short test of content focused on in GMAs (and associated lessons) was devised (see Appendix 9).

For three classes who took both pre and post-tests an increase in scores was found, however, given the content was related to the Y3 mathematics curriculum an increase would be expected. When compared with a comparison cohort who took the test at the end of Y3, the 2016/17 cohort who experienced the embodied mathematics materials had significantly lower test scores than the previous year's pupils. This outcome should be treated with some caution (as would any high scores if they had been found). This could be due to an underlying difference between the cohorts. Details are provided in Appendix 15.

The table below gives the mean of the test scores for the 2017 summer multiples test for the EMP cohort with the previous year's cohort across the two schools.

Table 8.2.2a Comparing mean scores

School	2016 cohort	2017 post test
Lydgate	8.3	8.5
Hunter's Bar	8.7	7.9

However, when the lowest 9 students are excluded from the data at Lydgate then the means are the same - so the test scores suggest the increase overall is due to higher scores for the lowest attaining pupils.

Table 8.2.2b School 2016 and 2017 test score frequencies

Lydgate				Hunter's Bar		
	2016	2017			2016	2017
Score	Freq	Freq		Score	Freq	Freq
10	8	22		10	50	26
9	11	15		9	9	12
8	14	7		8	7	18
7	3	5		7	3	6
6	1	3		6	5	5
5	1	3		5	3	6
4	0	0		4	2	3
3	3	0		3	0	1
2	1	0		2	1	1
1	1	0		1	2	2

9 OUTCOMES AND IMPLICATIONS

In this section the outcomes of the project and implications of these are considered in relation to the initial project aims:

- design, develop and evaluate curriculum materials, activities and pedagogy informed by movement based and ensemble practices
- develop appropriate professional development activities
- examine how teachers can mediate embodied and ensemble learning to impact on pupil learning and attitudes
- identify appropriate evaluation methodologies and tools for assessing outcomes of embodied activities
- assess outcomes for teachers of engagement in professional development
- and assess learning and social outcomes for pupils.

These different aims and aspects of the project and evaluation are intertwined, but are considered separately, notwithstanding this leading to some overlaps.

9.1 OUTCOMES AND IMPLICATIONS FOR DESIGN AND FURTHER DEVELOPMENT OF CURRICULUM MATERIALS, ACTIVITIES, PEDAGOGY AND PROFESSIONAL DEVELOPMENT ACTIVITIES

In this section outcomes of the project and implications in relation to the first two aims are considered, that is for design and further development of curriculum materials, activities, pedagogy and professional development. Project components are considered separately.

9.1.1 Workshops

During the projects, the practitioner-led workshops evolved from emphasising experiences for pupils to professional development experiences for teachers. They also shortened in length. The format used at the end of the project was successful and valued by teachers. A number of teachers noted that there was potential for gaining more professional learning if a debrief discussion could be timetabled and also if co-observation with other teachers involved in the project could take place.

9.1.2 Being a Mathematician

This strand was valued both implicitly and explicitly by some teachers in London 2015/16 and may be worth further exploration though the form of drama used in activities is distinct from the ensemble physical theatre tradition.

9.1.3 Group Mastery Activities

This was an emergent component of the project. It brought aspects of outside classroom activities into the classroom space, and gave opportunities for developing the ensemble in the classroom. The development of this new component represents a significant success of the project.

Teacher feedback, included above, offers useful advice and suggestions, as well as adaptations that could be incorporated into descriptions of GMAs. If they are to be used

beyond Y3 and engage all pupils, attention is needed to considering the mathematical challenge of activities. The issue of mathematical challenge was raised by teachers and also by some pupils in focus groups. Further, the test data for comparison pupils shows that by the end of Y3 many pupils will have learned the mathematical content regardless of engaging in GMAs. This is likely to only become more important in the future given the planned introduction of the Y4 national multiplication test. Anecdotally, already schools are responding to this by planning for all pupils to know multiplication facts up to 12 x 12 by this point and further accelerating learning of multiplication facts in Y3. Thus, the mathematical content of GMAs may need developing to address this content, if teachers and head teachers are to be convinced that GMAs will support the required level of factual knowledge and fluency.

However, there may be a tension between ensemble experience, the aesthetics of using movement and rhythms work to explore multiples of numbers 1-12, and the degree of mathematical challenge. This could be explored in future developments.

9.1.4 Lesson activities

Many of the lesson activities were positively received and were successful. Note that for most activities, possible effect on pupil learning was not assessed.

As a design project materials were produced during the year. If Sheffield teachers had access to place-value materials at the start of the year then these would have been better timed for them. In the current context in primary schools, number activities are likely to be better received than other activities.

The appropriateness of symmetry activities for older children is worth further investigation but their use in Y3 was not recommended by the teachers who had used them. For those activities that addresses multiple and factors the way that the new Y4 multiplication test may influence content in Y3 and Y4 should be considered, as pointed to above in relation to GMAs. However, this may be less of a concern in relation to the lesson activities given their focus on supporting conceptual understanding of underlying mathematical structures rather than a main focus, mathematically, on knowledge and fluency.

As discussed above, teachers were positive about how lesson activities were presented. One improvement would be if any additional materials or resources could be in the same file as the lesson or activity description rather than a separate file. This would make printing materials for lessons simpler and avoid starting a lesson with missing materials.

Issues with children's attention span and access to spaces outside the classroom suggests that rather than presenting material as 'lessons' it may be better to present them as a set of linked activities.

9.1.5 Performance

Like GMAs this was an emergent aspect of the project, which drew on and developed from other Complicite work connecting mathematics, movement and performance. In general this was well received and both performance forms - to peers/school community and to parents - were successful.

9.1.6 Professional development

Positively, both formalised professional development activities and engagement in the project had a range of professional development outcomes. The overall balance of encouraging engaging in the substantive mathematical activities and considering their use in classrooms was successful. It was observed that working with mathematical concepts in new ways led to deeper understanding for some teachers. It may be that working in a way that is unusual or exploring mathematics in different contexts allows for mathematics primary teachers to engage mathematically and so deepen understanding without having to address complex affective relationships including some anxiety and shame.

What activities constituted professional development evolved, as noted above, and school workshops' became more consciously a CPD opportunity. This was found to be effective. If twilights are used it is important to ensure that these are planned and purposeful with new content rather than only being opportunities for reflection.

9.2 TEACHER MEDIATION OF ACTIVITY TO SUPPORT LEARNING AND POSITIVE RELATIONSHIPS TO MATHEMATICS

Teachers clearly had an important role in successful use of project activities. Central here was how they encouraged the development of ensemble and collaborative ways of thinking. In many cases this drew on and depended upon their personal existing practice and/or that of the school in relation to social learning of pupils. However, also important was the modelling of this by Complicite practitioners and the communication of ensemble 'local theory' that teachers could use in facilitating activities. 'Local theory' here refers to principles such as the power of the circle, of taking time, the recognition that acting as an ensemble is challenging, as well as strategies for addressing individuals who found it difficult to engage as part of the ensemble. This modelling happened both in CPD days and workshops. In addition, teachers welcomed coaching on addressing challenges including resistant pupils.

Another form of mediation was teachers' flexibility and capacity to adapt materials and activity within their specific contexts, specific needs of their class and type of spaces available to them.

As noted in Section 6, the existing dispositions and capacities of the teachers engaged in the project(s) and support by their school leaders were important to implementation. Generally, participants were self-selected and willing participants. If working with teachers whose initial disposition, and/or experience of working in similar ways, was less favourable, attention to additional support may be needed.

9.3 DEVELOPMENT OF EVALUATION TOOLS

A number of evaluation tools were designed and used in the project. Many of these tools appeared fit for purpose including forms for reflection on activity use and interview schedules. Further, the balance of evaluation activities did not appear to be overly burdensome on teachers.

The mathematics test, whilst appropriate in terms of challenge at the start of Y3, gave a skewed distribution at the end of Y3. Further, it can be anticipated that, given the further emphasis on multiplication facts, that expectations of Y3 will increase. If a mathematics test is used in future, consideration to design and ideally piloting would be advised.

Teachers in Sheffield reported positive outcomes of other lesson activities that were not tested, such as place value and fractions, and consideration to assessing these outcomes could also be given.

Teachers of Y3 reported that some pupils found the attitude survey format challenging. It is also notable that there was considerable fluidity in both the Sheffield and London samples to changes in attitudes over the year with a large majority of pupils' attitudes either becoming more or less favourable and only a small minority whose attitude stayed the same. This raises an issue that, as far as we are aware, is not discussed in the research literature in this area - fluidity of affect. Generally, affect towards mathematics, and other specific areas such as learning with others in mathematics, is taken as a relatively stable construct. However, this may not be the case for this age of children. The data suggests further work is needed to explore this issue separately from the use of a scale in a particular intervention.

For convenience, and given limited resource, a survey designed for Y6 pupils was adapted. On reflection, this may not have been appropriate, given the lack of familiarity with the Likert form. To address the issue of pupils' unfamiliarity with Likert type scales, a redesigned survey might have fewer items, with, for each item, only three responses, and these being given in full sentences with pictorial response options (happy, neutral, unhappy faces).

It may be that there are wider changes in a sense of belonging in the class than those assessed in the attitude survey, changes around learning together versus individually in mathematics classrooms. It may also be the case that alternative research methods - such as ethnographic methods - may serve to investigate in more depth teacher perceptions of change and learner experiences.

9.4 IMPLICATIONS OF OUTCOMES FOR TEACHERS AND PUPILS AND EVALUATION OF PROJECT DESIGN

9.4.1 Teacher outcomes

The project was effective in leading to increased capacity to use movement activities to support mathematical learning, as well as more in depth understanding of how to support and foster collaborative learning through ensemble activities.

There was evidence for some teachers of change in terms of their pedagogical orientations and thinking about mathematical ability. Thus, the project demonstrated potential for teacher change that ranged from extending skills - or retooling (Sachs, 2011) - to more transformative change of re-imagining (ibid). The latter form of learning would be more likely in the future if teachers' suggestions of ways to deepen the collaborative learning

were taken up; these related to learning between themselves (through peer observation) and with practitioners (through post workshop discussion).

9.4.2 Pupil outcomes

Teachers reported important outcomes in terms of a sense of togetherness and the capacity of some individuals to collaborate. Both Sheffield schools were Junior schools and so pupils had just joined. This may have heightened the importance of the development of classroom communities. Another point of transition is when moving to secondary schools. Adapting activities to support a sense of togetherness or ensemble in Y7 classes is one possibility for future exploration.

In relation to mathematical learning, evidence is mixed or, in relation to sub-projects that used lesson activities, there is only anecdotal evidence about many content areas, for example fractions. This could be explored further in the future.

9.4.3 Project design

Based on the preceding discussions, the issue of overall project design is now addressed.

There were three different approaches used in the three sub-projects, as well as other possibilities. In this section, implications of the study for different potential further developments are considered. These are described in terms of 1) Embodied Mathematics, conceived as broadly similar to the structure of the Sheffield project and 2) Ensemble Mathematics, structured in a similar way to London project.

9.4.3.1 Embodied Mathematics

The EMP led to both refinement of existing embodied and movement activities and creation of original activities produced as a set of modules. As such it takes forward previous work in this area in the primary mathematics context. EMP extended notions of what is possible within classroom settings. Within the constraints of access to outdoor spaces, it is not feasible to consider that lessons outside the classroom can be the sole basis of mathematics curriculum. The number of lessons suggested appears at the limit of what is practical for teachers to implement. However, teachers used the experience of teaching outside the classroom to adapt activities and use classroom spaces in creative ways. Working outside the classroom supplemented classroom based lessons and appears to support reconfiguring classroom relationships.

9.4.3.2 Ensemble Mathematics

The London 2016/17 project represented the development of a focus on the ensemble aspects of activity in and outside the classroom. The contention of the practitioners is that engaging in GMAs regularly will lead to higher mathematical attainment. The evaluation data does not provide strong independent evidence for that. However, teacher reports suggest there may be value for individual pupils in terms of mathematical learning.

Further, teachers reported the value in terms of developing a sense of learning together. In the context of the two Sheffield schools, this was possibly particularly important given that pupils were transitioning from infant to junior schools and finding themselves in new

classes. Another primary context where ensemble and GMA activities may be of particular value is where schools move from attainment grouping to more heterogeneous practices.

One teacher noted:

> The ensemble way of working has been very rich but it has been very challenging at times. I think when I really think about it, there are very, very few opportunities in school for children to really work together as a class in that large sort of group. We do a lot of group work. They might be working in twos, threes, fours, sixes. But for children to be really, really meaningfully working together, in that large ensemble, I certainly don't have many opportunities aside from when we do circle time and things like that for that sent of coming together, working together and supporting each other. (Sheffield teacher 3)

As discussed above a number of teachers described how they had engaged in discussion with classes about the importance and value of being able to do ensemble activities and had scaffolded this to some extent and had intervened to support success. It may be useful to include teacher-authored suggestions on how best to do this in GMA descriptions.

If GMAs are to be used with Y4-6 or, depending on future developments, with Y3 then there are some indications that mathematical learning demand would need to be increased for the activities to be taken up by teachers and for (all) pupils to find them challenging.

10 CONCLUSION

The Embodying Mathematics Project drew on previous work by Complicite and by the wider mathematics education community. It aligns with current interests in STEAM (Science, Technology, Engineering, Arts and Mathematica education) that seeks to synthesise art-based pedagogies and, in this case, mathematics education. One criticism of the STEAM approach is that the arts, and specifically drama, can be 'handmaidens' to STEM subjects. Arguably, the EMP avoided this in that movement activities were put at the centre of project design. The EMP also represents a curriculum development project that provides an example of the application of current theoretical and methodological interest in embodiment in mathematics.

Whilst evidence of impact on pupil attitudes or attainment from surveys and tests was not found, this was not anticipated in this initial design/pilot phase of the project. Data from teachers suggests that the project had a number of positive outcomes for pupils. Indications were found that ensemble pedagogies may promote a greater sense of belonging in the class and this could be worthy of further investigation, possibly with mathematical learning as a vehicle rather than the main intended outcome. Further design and piloting could be undertaken to firstly gather evidence of outcomes in more depth and/or to refine activities to lead to greater attitudinal change and mathematical learning.

The EMP led to the development of a variety of innovative curriculum activities focused on mathematics and movement, with particularly interesting areas being the extension of movement activities to focus on multiples and factors and the development of Group Mastery Activities. The project had a number of positive outcomes for teachers and pupils. A rich set of mathematical activities were developed and the experience of at least 24 teachers and up to 700 pupils was enhanced. Importantly, the project led to greater clarity about meanings of ensemble pedagogy and collaborative learning for the designers and teachers.

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12 APPENDICES

Appendix 1: EMP overview of module content London 2015/16

Module one - Patterns

Lesson one: Patterns in circles
Learning space: hall / gym / playground

Lesson two: Throwing the wool
Learning space: classroom with, say, a 3m x 3m demonstrating space

Lesson three: Making rectangles
Learning space: hall / gym / playground

Lesson four: Finding factors
Learning space: classroom

Lesson five: Twos and threes
Learning space: hall / gym / playground

Lesson six: Patterns on grids
Learning space: classroom

Module 2 Position and rules

Lesson one: Loci
Learning space: hall / gym / playground

Lesson two: Curves of pursuit
Learning space: classroom

Lesson three: Right angles
Learning space: hall / gym / playground

Lesson four: Square spirals
Learning space: classroom with, say, a 3m x 3m demonstrating space

Lesson five: Co-ordinate grid
Learning space: hall / gym / playground

Lesson six: Transformations
Learning space: classroom

Module 3 - Doing and undoing

Lesson one: Getting there and getting back
Learning space: hall / gym / playground

Lesson two: Inverses
Learning space: classroom with, say, a 3m x 3m demonstrating space
Additional material: *Doing and undoing* work card

Lesson three: Think of a number
Learning space: hall / gym / playground

Lesson four: Function machines
Learning space: classroom
Additional material: *Mapping* work sheet, *Making machines* work sheet

Module 4 -In space

Lesson one: Four sides and symmetry
Learning space: hall / gym / playground

Lesson two: Square, rectangle, rhombus, kite
Learning space: classroom
Additional material: *Square, rectangle, rhombus, kite* work sheet, *Quadrilateral symmetries* work sheet

Lesson three: Types of triangle
Learning space: hall / gym / playground
Additional material: *Thinking about triangles* information sheet

Lesson four: More about triangles
Learning space: classroom
Additional material: *Types of triangles* puzzle cards, *Nine pin triangles* work sheet

Appendix 2 Example of a lesson from London Year 1 Module 1 lesson 1

Patterns in circles

Learning space
hall / gym / playground

Materials
three hats to mark zero, three bean bags, three large sheets of sugar paper, three suitable making pens

Activity 1: All together
The children stand in one large circle equidistant from a bean bag.

Starting with the teacher, everybody jumps once in turn around the circle. The jump stops when it gets back to the last person before the teacher. Repeat with everyone trying to make a smooth pattern in the jumping.

Again starting with the teacher, jump in pairs of two around the circle.
If the number in the circle is even, then the pattern will be finished in one revolution.
If the number is odd, continue the jumping round the circle until the jump gets back to the beginning.
Draw attention to whichever happens.

Again starting with the teacher, jump as groups of three around the circle.
Continue the jumping round the circle until the jump gets back to the beginning.
Draw attention to whether or not once round the circle is all that is needed.

Ask for explanations.

"When do we need to go round more than once?"
Why?"

Repeat with groups of four and then groups of five.
Again, discuss the results.

Activity 2: Throw and catch
By leaving the circle or not, make the circle even. Choose a child to be the starter and give them a zero hat to wear. Suppose there are, say, 26 people in the circle. Count round from zero and notice that the starter is also 26. This gives the number of people in the circle. Continue counting round so the starter becomes 52.

"Why do we get 52?
What would happen if we went round three times?"

Choose another child to be the starter. Give them the zero hat.

"Starting with zero, throw and catch an imaginary ball round the circle to every second person.

Stop when the ball gets back to the starter."

Change the 'zero hat' to another child. Repeat but this time chanting the numbers together.

" When the first person throws, we all say 2, when that person throws we all say 4 and so on."

Change the 'zero hat' to another child and, by leaving or joining the circle, make the circle odd.

"Throw and catch an imaginary ball. Again to every second person. Stop when the ball gets back to the starter."

This time you will have to go round twice.

Change the 'zero hat' to another child. Repeat but this time chanting the numbers together.

There will be debate about what to do when the ball is held by the child immediately before the starter.

"Let's keep going until we get back to the starter.

The last number will be 52."

"Why did we have to go round twice?"

Activity 3: Throwing in groups

Ask the children in silence to split themselves into three unequal groups.

Give each group a zero hat, a bean bag, a sheet of sugar paper and a suitable marking pen.

"In your groups, make a circle.

Throw an imaginary ball 2 spaces, 3 spaces, 4 spaces and so on.

When do you need to go round more than once?

How many times do you go round?

Record what happens on your paper."

Ask the children, in each group, to choose one of their throwing patterns to show.
Ask them to rehearse it, with or without chanting.

Ask each group to show their rehearsed pattern.
Ask each group to share what they have found out.

Appendix 3 EMP Module overview Sheffield

Module: Multiples and factors

Lesson one: All together
Learning space: hall / gym / playground
Activity 1: Making the circle
Activity 2: Moving together
Activity 3: Walking the space
Activity 4: Counting together
Lesson two: Common multiples
Learning space: classroom
Activity 1: Counting together again
Activity 2: Lowest common multiple
Lesson three: Jumping in circles
Learning space: hall / gym / playground
Activity 1: Jumping numbers
Activity 2: Round and round
Activity 3: Jumping chains
Lesson four: Zigs and zogs
Learning space: classroom
Activity 1: How many pets?
Lesson five: Making rectangles
Learning space: hall / gym / playground
Activity 1: Jumping numbers again
Activity 2: Factors and rectangles
Activity 3: Jumping rectangles
Lesson six: Finding factors
Learning space: classroom
Activity 1: Factor rectangles

Module: Working with number

Lesson one: Numbers in order
Learning space: hall / gym / playground
Activity 1: Counting up and counting down
Activity 2: Biggest and smallest
Lessons two: Hundreds, tens and ones
Learning space: classroom with demonstrating space
Activity 1: Showing number sequences
Activity 2: Number chain
Activity 3: Numbers from my hat
Lesson three: Getting there and getting back
Learning space: hall / gym / playground
Activity 1: In the ring

Activity 2: Making action sequences

Lesson four: Inverses

Learning space: classroom with demonstrating space

Activity 1: Sharing action sequences

Activity 2: Doing and undoing

Activity 3: Making a poster

Module: Polygons and their symmetries

Lesson one: Symmetries of a square

Learning space: hall / gym / playground

Activity 1: Round the ring

Activity 2: Working with a square

Lesson two: Quadrilateral symmetries

Learning space: classroom

Activity 1: Folding a square

Activity 2: Four lines of symmetry of a square

Lesson three: Types of triangles

Learning space: hall / gym / playground

Activity 1: Ring reflections

Activity 2: Symmetries of an equilateral triangle

Activity 3: Making triangles

Lesson four: More about triangles

Learning space: classroom

Activity 1: Triangle puzzle

Activity 2: Folding triangles

Module: Angles and lines

Lesson one: Right angles

Learning space: hall / gym / playground

Activity 1: All together

Activity 2: Making squares

Lesson two: Robots

Learning space: classroom with demonstrating space

Activity 1: Robot walks

Activity 2: Drawing robot walks

Lesson three: Loci

Learning space: hall / gym / playground

Activity 1: All together

Activity 2: Follow the rule

Activity 3: Angle bisectors

Activity 4: Parabola

Activity 5: Parallel and perpendicular

Lesson four: Perimeter

Learning space: classroom

Activity 1: Walk round the outside

Activity 2: Six squares

Module: Fractions

Lesson one: People Fractions

Learning space: hall / gym / playground
Activity 1: Class fractions
Activity 2: Fractions within fractions
Activity 3: Fraction moves
Activity 4: Fraction freeze frames

Lesson two: Representing fractions

Learning space: classroom
Activity 1: Fractions we made
Activity 2: Counter fractions
Activity 3: Fraction circles
Activity 4: Your fraction poster

Appendix 4 Example of lesson activity Sheffield 2016/17

Module: Multiple and factors, lesson 1

All together

Learning space hall / gym / playground
Materials bean bag
Key mathematical concepts common multiples
Mathematical learning The aim of this lesson is provide tools to develop fluency in working with whole numbers. The children will practise known results in the 2, 3 and 5 multiplication tables and have an initial experience of common multiples.
Ensemble focus In this lesson children are introduced to the circle and its value and importance for working effectively together. They are introduced to the idea of being aware of everybody and of working together without "leaders".
National Curriculum Programme of Study • recall and use multiples of 2, 3 and 5 developing fluency

Activity 1: Making the circle

We are going to work as an ensemble, which means working all together and thinking together.
If the activity goes wrong, it's everyone's responsibility.

Put a bean bag on floor.
Ask people to stand so that everyone is standing exactly the same distance from the bean bag.

Teaching point

The circle makes everyone equally important. And everyone can see everyone else.

The mathematics

A circle is defined as all the points which are exactly the same

What is the shape we have made?
Why might it be a good shape for working together?
Check that you can see everyone, and enjoy that we are all working together.

Move the beanbag and reform the circle.

Have we made a circle the same size as before?

Now we are going to try something very hard, but very important. We are all going to try and see EVERYONE AT ONCE.
How can we do this?

Help the children to realise that by not looking at anyone special we can put everyone into our peripheral vision.

Let's all do it.
Now can you do it without moving your head at all? Yes!
Why?

Our bodies and brains are very, very good at working and thinking together. We can all do it.

Activity 2: Moving together

Now we are going to think together.
We are going to all put our hands in the air at EXACTLY THE SAME TIME.
Someone watching should not be able to see anyone "leading".

Do this as many times as you like. The group will quickly get better at it. Remark on this.

What do you notice?
What do you feel?

You may find that you are "leading". This usually happens to start with and is fine, but you will eventually want to remove yourself and watch them do this by themselves. You may also want to pick pupils to stand outside and watch to see if anyone is "leading".

Can we all clap exactly together?

Repeat as necessary.
Reinforce that this is thinking together.

Teaching point

This idea of an observer, here and below, will feature in the "group mastery activities" which are designed for use in the classroom. This exercise of raising hands together is the basis of these

Activity 3: Walking the space

Now we are going to explore the whole space.

The group walk gently and slowly round the space in silence. Not in circles, and not with anyone else. They should imagine they are alone, and not look directly at anyone. They should try and keep the whole group in their peripheral vision, so that they "know" where everyone is. Then, by thinking and working together, find the exact second where everyone stops together. Again, you may find that they follow you, the teacher, so ideally work towards eventually them doing this with you observing. Stress the idea that if they really try hard to work together, the stopping is "magic". Then move to them both stopping and starting together. You may then want to remove groups of pupils to watch, and see if they can tell if anyone is leading.

What do you notice?
What do you feel?
What do you like?
What do you not like?

And now, from where we are, can we again all raise our hands exactly together?

Teaching point

Whenever you are in a large space, this activity can be used at any time to improve the attention and awareness of the children as members of a learning community.

Activity 4: Counting together

All sit in the most beautiful circle.
Establish a simple beat.
All count together, clearly but quietly. To perhaps 15.
Count again. This time, all raise both hands on every multiple of 2. Count to 24.
Count again. This time, all raise hands on every multiple of 3. Count to 36.
Count again to 36. This time, half the circle raise their hands on multiples of 2, the other half on multiples of 3.

Are there numbers at which we all raise our hands together? Which are they? Why?

You may need to repeat this exercise several times until all keep the rhythm all together. Now try swapping the two groups over.

IF TIME ALLOWS

Count to 60. This time all raise hands on multiples of 5.
Count again to 60. This time, a third of the group raise hands on multiples of 2, 3 and 5.

When do we all raise hands together?

Again, repeat the count until all keep the rhythm all together.
Again, swap groups and repeat.

The mathematics

All hands are raised together first when the lowest common multiple (LCM) of the numbers is reached. After that, all hands are raised together on multiples of the LCM. Lesson two explores this mathematics in more detail.

Teaching point

Do not expect the children to easily and fully grasp all the mathematics in this exercise. It is intended to provide an introduction to the group mastery activity which will be repeated with growing depth of understanding as the year progresses.

Something to think about. If we counted in 3s, 4s and 5s, when would we first be all together? Why?

Finish the lesson by standing up, and all raising hands together.

Did anyone learn anything new?
What does it feel like to think an

Being a mathematician

Looking for patterns.

Appendix 6 - Group Mastery activities (London 2017 version)

GROUP MASTERY ACTIVITIES

Group mastery activities (GMAs) support the class learning together and developing mathematical fluency. The aim is that everyone has a sense of mastering the activity **together.**

Once a class is familiar with a GMA, it can be done in a short amount of time - as little as **5 minutes**. It can be done:

- at the start or end of every mathematics lessons
- in short slots that have been timetabled for arithmetic practice
- as transitions between other activities at any time during the school day.

These GMAs are designed to be done in the classroom regularly. Ideally this would be daily. During the project we're asking you to do them **at least three times a week**.

GMAs should be steadily developed over time, and you will need to keep returning to them with your class to make the most of them. Think of it like practising a sport, which you would never expect to master in a single session, or a piece of music which you get better and better at every time you repeat it. We think it will take a term to master this set of GMAs, even if you spend five minutes on them day.

These activities are intended to be flexible and we hope that you will develop and change them, and add in the mathematical content that is appropriate for your class. If you do, please keep a record of what you've done and let us know so we can steal your ideas for the future!

The GMAs come as 8 cards, which describe the 8 stages in which we think they should be taught. These are also flexible, though, and once you've got comfortable with each stage you should feel free to move through them in whatever order is useful or exciting for your class. On the back of some of the cards is additional mathematical content that you could add on to each stage but, again, this is by no means exhaustive and should be the starting point for you to explore the mathematics that's relevant to your class.

1.

The whole class sits in silence at their desks. Introduce them to the idea of the ensemble. An ensemble of people can think together, and they can be an ensemble if they try hard.

Ask everyone to be aware of everyone else in the room. Can each child see every other child without moving their heads? Ask them to try. If not, can they see everyone by moving their heads? Do it. Then ask them to close their eyes and see everyone in their minds.

Open your eyes. Now ask the pupils to raise both their hands into the air exactly together. They'll need to move very slowly at first and be very focused on one another.

You can be part of the class ensemble to start with. Initially you may find that you are slightly leading and this is fine, but you should gradually withdraw yourself as the class gets more confident.

Once they've done it, ask them how it was possible, even though they couldn't all see each other. (Although we may not be able to see everyone, we can think all together.) Do it again. Ask the group how it feels.

You don't need to do this every time, but throughout these activities you can ask individual children to step out and watch and comment on how the ensemble is working. What do they like about what they see? What looks good?

2. Now, come back to silence and readiness.

Ask everyone to be aware of everyone else in the room.

Establish a slow beat, by tapping gently on a table. Once the beat is established, ask the class to count up to 24, in time with the beat. The counting should be quiet: little more than a whisper. Can you hear everyone in the class counting? Can they all hear each other? If they can't, count more quietly, and listen more carefully.

Once you're confident that they're really able to listen to each other as they count, change the instruction slightly. Ask the class to count to 24 again, this time raising their arms if the number is a multiple of 2.

Do it again, and ask everyone to try and raise and lower their arms at exactly the same moment. Make sure the count is perfectly in time. You'll need to keep the beat slow and steady to ensure this.

<u>Maths layers</u>

- Tell the class they're going to count up to 24, raising their hands on every multiple of 2, as they have been doing. Ask them to predict how many times they will raise their arms (12).
- Check this prediction. Ask half the people at each table to be 'counters'. Now, as you repeat the root, the 'counters' will count how many times the class raise their hands. So, for example, as the class speak '2' and raise their hands for the first time, the counters will say '1'. As the class say '4 ' and raise their hands for the second time, the counters will say '2'. Stop at 24 and ask the counters how many times the class has raised their hands.
- Explore this. As the class say '12' and the counters say '6', can you draw attention to the fact that 2 x 6=12?

3.

Now ask the class to count to 36, raising their arms on every multiple of 3. Keep up the beat for them to follow, but ask them to count in their heads, speaking only the multiples of 3 out loud.

Keep asking yourself whether they're listening to each other as well as speaking. You want to make sure they're really able to focus on working as a group, raising their arms and speaking (or whispering) in time with each other, and on hearing the numbers.

Maths layers

- Ask the class to predict how many times they will raise their arms as they count to 36. Choose counters to keep track of this. Notice that the counters are also marking the multiplication tables.
- Now count up to 48, raising hands on every multiple of 4. How many times will they raise their arms? (12) Choose counters to help you keep track. Point out that they will raise their arms the same number of times as when they counted to 24 and raised on multiples of 2. Why is this?

4.

Divide the class into two groups. *To start with, choose the simplest way of dividing them, but as they get more confident with this activity you could vary this and split them in more complicated ways, or ways which give rise to more interesting patterns around the classroom.*

Establish the beat and ask one half of the class to raise their hands on every multiple of 2, and the other half to raise their hands on multiples of 3.

Maths layers

- Invite one of the children to observe. What do they notice? When does everyone raise their hands together? Is there a pattern to that, and what is the pattern? This gives you the opportunity to talk about common multiples.
- Repeat the activity with multiples of 2 and 4, and observe the fact that children counting 4s will raise their hands half as often as those counting 4s. What does this tell them about the relationship between 2 and 4?
- Repeat the activity with multiples of 2 and 5, 3 and 5, and so on, and keep asking them to observe patterns and make predictions.
- Split the class into 3 groups. With everyone counting up to 30, ask one group to raise their hands on multiples of 2, one on multiples of 3 and the third on multiples of 5. What does the group notice about the relationships between the numbers? When do they all raise their hands together? (On 30 and 60 in this example.) Are there moments when 2 of the groups raise their hands and the third group doesn't? (Yes, on multiples of 6, 10 and 15 in this example.)
- Are there numbers on which no one raises their hands? (The primes apart from 2, 3 and 5 and also all the numbers which are not multiples of 2, 3 or 5.) Can anyone think of a number where no-one raises their hand but the number isn't prime? (Hard question - 49.) Pursue this as far as you want.
- Try it again, with the 3, 4 and 8 multiplication tables. Can you make predictions about when everyone will raise their hands together? If not, ask some of the children to step out and watch and keep count.

5.

Tell the class that they're going to play a beautiful ensemble game. They are going to create a 'loop' around the classroom in which each child will stand and sit in a sequence. *If your class has an odd number of people in it, you will need to join in and be the last person in the loop, making the number even.*

Choose one pupil to start creating the loop. They will stand up, sit down and then indicate, without speaking or overtly gesturing, that the person next to them should take their turn to stand and sit. The second person then turns to their next nearest neighbour (probably the person sitting on their other side). Again, using only eye contact, the second person will

show the third person that it is their turn to stand and sit. Each child will need to remember who came before and after them in the loop.

Continue around the classroom until everyone has stood once and you've created a complete loop of all the children. It's best to get each child to choose the person closest to them to stand with, so you'll need to watch out for when the loop has to jump from one table to the next – but it should work fine.

The whole class should watch the loop carefully, and check in their own minds that everyone in the ensemble has 'been'. They should also make sure they're performing their loop beautifully: are they silent? Are they taking enough time?

Maths layers

- As each person stands in the loop, they should count themselves, starting with 1 and ending with the total number in your ensemble. This is a very nice way of remembering that your ensemble is made up of a certain number of people and that that number might change from day to day. Do they feel any different when people are absent from the class?
- Try practising multiplication tables like this: as each person stands, ask them to say the next number in whichever table you're learning.
- Expand this to any relevant maths you're working: start with a number and double it, or add 5 each time, or subtract 3.

6.

When the sequence is firmly rooted, perform the loop again, but this time ask the children to stand and sit in pairs. Make sure they stand at exactly the same time, and sit down again at exactly the same time. How is it possible for two people to do something at exactly the same time, without speaking?

Go round the loop until everyone has had one turn at standing with a pair.

Your group should have an even number of people in it, so you should only need to go round once, but of course you can go round as many times as you like.

Maths layers

- As the class are standing together in pairs, add in any times tables that they are currently working on: when the first two children stand, they should look at one another and, using the same principle of unspoken agreement, say the first number in the times table (eg. '2'), when the next two stand, they should say the next number (eg. '4') and so on. How can two people speak at the same time?
- Before moving through the loop, give the class a starting number and a number to add or subtract from this. This time, as each pair stands, they should look at one another, agree silently that they have each got an answer, and together speak the next number in the sequence.
- You could also use this exercise to practice number bonds: one of the pair should say a number below 10 (or 20, or whatever you're working to) and the other replies with its number bond.

7.

If you were part of the original loop, you should now take yourself out, even if it means the group has an odd number of people.

Move round the loop in pairs but, this time, if there is one person left when you've gone round once (i.e. if your group has an odd number of people), carry on around the loop until everyone has had a go. This will mean the pairs change, and each child moves with a new partner.

Ask the whole class to watch and make sure that the beauty of the loop is maintained, and that each pair sits and stands exactly together. Ask them what they see, and what they feel. Perfect your loop: can it be smoother? Can the children gradually speed up, and still stay smooth? Ask the class what they like about it. How beautiful can they make it?

Maths layers

- Ask your pupils about the numbers in the loop. If you go round the loop once, is anyone left out? What does this tell us about the number of people in the group? Is it odd or even? Is it a multiple of two?
- If someone is left out (i.e. if the number in your group is uneven) ask the children whether they can think of a way to include that last person. (They will need to go round the loop a second time, essentially multiplying themselves by two.) Will each person

stand with the same person the second time round? (No.) Will someone be left out again after the second time? (No.) Why? What sort of number have they made by going round twice (i.e. by multiplying by two)?

8.

Now ask them to stand in 3s. They must still find a way of all standing together, with no one leading, and no one left behind. You will need to practise it a few times. How is it possible to do it without speaking? Is standing in 3s different from standing in 2s?

Maths layers

- Ask the class to think about how many people are left over after one cycle of this loop, and what that tells them about the number in the ensemble. Is it a multiple of 3? If not, how many times must they go round to make sure no one is left out? Try out their conjecture and see if they are right.
- Perform the very first version of the loop, with each child standing individually. Once you get to the end of the sequence, continue on around the loop with the children standing in pairs. (They may need to complete the loop twice to ensure that everyone stands.) At the end of the sequence, continue on with children standing in 3s. Again, repeat the loop as many times as necessary to ensure that everyone stands. Finally, go back down: repeating the loop in 2s, and then finally in 1s.

Appendix 7 Being a mathematician

Being a mathematician qualities London 2015/16

Quality	Different aspects (statements to exemplify the quality)
Mathematicians love patterns	• looking for patterns • making connections • describing patterns
Mathematicians explore	• playing around with ideas • being creative • making pictures in your mind, on paper or with the body
Mathematics think	• taking time to think • asking yourself questions • making a conjecture and checking it out
Mathematicians like challenges	• getting stuck and keeping going • making mistakes and using them to learn new things • justifying your thinking
Mathematicians learn together	• talking about mathematics and explaining your thinking • working with others • helping others and being helped by others
Mathematicians move	• acting out the maths • showing the maths • moving to get a different point of view

Appendix 8 Pupil Attitude Survey

Embodying Mathematics Project pupil attitude survey 2016/17

Name …… Year……..

Teacher……

This survey is about your attitudes to mathematics. It has two parts

The survey is a set of statements and you have to decide if you agree or disagree with them. There are five choices from strongly agree to strongly disagree.

There are no right or wrong answers. This is about what you think. Everyone may have different answers - that is fine.

Examples

Here are two examples to try before you start. Once you have done them stop and wait for your teacher to tell you to start the survey:

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I like reading books better than I like watching TV	❍	❍	❍	❍	❍
Riding on a scooter is easier than riding a bike with training wheels	❍	❍	❍	❍	❍

The survey

Please tick the circle below to say how far you agree with each statement. Once you have finished this section please wait for your teacher to explain the next part.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I often find mathematics hard	❍	❍	❍	❍	❍
I like mathematics	❍	❍	❍	❍	❍
In mathematics lessons I sometimes feel left out	❍	❍	❍	❍	❍
Mathematics interests me	❍	❍	❍	❍	❍
I prefer working alone rather than in groups when doing mathematics	❍	❍	❍	❍	❍
I enjoy mathematics	❍	❍	❍	❍	❍
I learn more about mathematics working on my own	❍	❍	❍	❍	❍
I feel confident in my abilities to solve mathematics problems	❍	❍	❍	❍	❍
In math's lessons, my class cares about each other's learning	❍	❍	❍	❍	❍
No matter how hard I try, I'll never be good at mathematics	❍	❍	❍	❍	❍
I often worry that it will be difficult for me in mathematics lessons	❍	❍	❍	❍	❍
I get nervous when I am working on mathematics problems	❍	❍	❍	❍	❍

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I enjoy working in groups better than alone in mathematics lessons	❍	❍	❍	❍	❍
I worry that I will get low marks in mathematics tests	❍	❍	❍	❍	❍
I look forward to mathematics lessons	❍	❍	❍	❍	❍
I am interested in the things I learn in mathematics	❍	❍	❍	❍	❍
Maths is best when the whole class works together on a problem	❍	❍	❍	❍	❍
I learn a lot from talking to other pupils about mathematics	❍	❍	❍	❍	❍
In mathematics everyone can learn together	❍	❍	❍	❍	❍

Part two - Complete the sentence

Words about mathematics.

Read the list of words or phrases that might be used about mathematics.

Choose the **four** that you think are the best one to complete the sentence - 'mathematics is about…'. Circle these **four**

Mathematics is about…….

making pictures	getting answers	using rules	exploring
the right method	being correct	understanding	trying things out
remembering	asking questions	patterns	problem solving

Being good at mathematics

Think about what sort of person is good at doing mathematics. Read the list of words and phrases.

Complete the sentence - 'someone who is good at mathematics…..

Choose **four** that think are the most important words or phrases about being good at mathematics.

Someone who is good at mathematics……

keeps trying	takes their time	has a good memory	is neat
works well on their own	uses the right method	can explain why	asks good questions
loves problems	is quick	tries out different ideas	is good at tests

Appendix 9 Mathematics multiples test and mark scheme

Maximum mark 10

1. Put a cross on **three** numbers that are **odd**

15	6	7
9	4	18

1 mark for all three

2. What is 5 x 10?

50

1 mark

3. Four of these number are in the same times t
Put a cross over the number which is not in tha
table

12	9	21	19	27

1 mark

4. Write down the two missing numbers in this pattern

12	16	20	24	28

two marks

5.. What is 16 ÷ 4

4

one mark

6. Sally counts up in fives starting from 5

Rebwar counts up in threes starting from 3

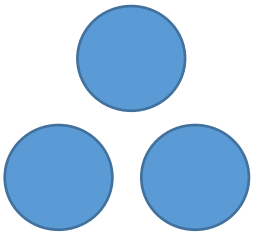
Write down one number they **both** might say

15 or any multiple of 15

1 mark

7. Hamda has 24 counters

a. She puts them into threes like this



How many threes can she make altogether?

8

1 mark

b. She now puts the 24 counters into fours.

How many fours can she make altogether?

6

1 mark

8. John plants flowers in rows

There are 8 flowers in a row
There are 4 rows

How many flowers has John planted?

32
one mark

Appendix 10 Summary of London teachers' survey responses

Note that 8 of 10 teachers completed the survey. There is a possibility of some response bias in terms of favourable views of the project.

Teacher experience

How long have you been teaching?

ANSWER CHOICES	RESPONSES	
0-2 year	0.00%	0
3-5 years	75.00%	6
6-9 years	12.50%	1
10 or more years	12.50%	1
TOTAL		8

Frequency of use of GMAs

How often have you used the group mastery activities in the classroom? An example of a group mastery activity is one where everyone raises an arm at the same time.

ANSWER CHOICES	RESPONSES	
Daily or nearly every day	0.00%	0
Two or three times a week	87.50%	7
Once a week	12.50%	1
Less than once a week	0.00%	0
TOTAL		8

Views on GMAs

Teachers expressed the following views on GMAs

	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE	TOTAL
The group mastery activities were effective in helping my pupils learn mathematics	12.50% 1	62.50% 5	12.50% 1	12.50% 1	0.00% 0	8
The group mastery activities helped develop a sense of togetherness	50.00% 4	37.50% 3	12.50% 1	0.00% 0	0.00% 0	8
Pupils found it hard to do the group mastery activities	12.50% 1	62.50% 5	0.00% 0	25.00% 2	0.00% 0	8
The information provided and professional development activity was enough to be able to do the group mastery activities	62.50% 5	37.50% 3	0.00% 0	0.00% 0	0.00% 0	8
I found it hard to lead the group mastery activities	0.00% 0	12.50% 1	12.50% 1	37.50% 3	37.50% 3	8
I used the activities flexibly and adapted them to suit my class	25.00% 2	62.50% 5	12.50% 1	0.00% 0	0.00% 0	8

Views on the amount of professional development

ANSWER CHOICES	RESPONSES	
There was too much time doing the different professional development activities	12.50%	1
The time for professional development was about right	87.50%	7
There was too little time for the different professional development activities	0.00%	0
Other (please specify)	0.00%	0
TOTAL		8

Views on the relative value of different activities that might lead to professional development

Respondents were asked to rank different activities in order in terms of activities that led to most professional development (1) and to least (5). The score is calculated by assigning a value of 5 to the most useful PD and 1 to the least. The professional development day was the most useful activity followed by using GMAs and Vic and Shane's workshops in schools.

	1	2	3	4	5	TOTAL	SCORE
The professional development day	87.50% 7	12.50% 1	0.00% 0	0.00% 0	0.00% 0	8	4.88
Twilight sessions	0.00% 0	0.00% 0	0.00% 0	25.00% 2	75.00% 6	8	1.25
Vic and Shane doing workshops in schools	12.50% 1	25.00% 2	62.50% 5	0.00% 0	0.00% 0	8	3.50
Support from Complicite on the performance day	0.00% 0	0.00% 0	0.00% 0	75.00% 6	25.00% 2	8	1.75
Using group mastery activities with my classes	0.00% 0	62.50% 5	37.50% 3	0.00% 0	0.00% 0	8	3.63

Professional learning

The table below provides details on teacher views of the professional learning that resulted from participation.

	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE	TOTAL
I am more confident to lead mathematics outside the classroom	25.00% 2	62.50% 5	12.50% 1	0.00% 0	0.00% 0	8
My ability to teach mathematics creatively has increased	37.50% 3	62.50% 5	0.00% 0	0.00% 0	0.00% 0	8
I have more strategies to develop a sense of a learning community in the classroom	25.00% 2	50.00% 4	25.00% 2	0.00% 0	0.00% 0	8
My understanding of ways to teach one or more areas of maths has increased	25.00% 2	75.00% 6	0.00% 0	0.00% 0	0.00% 0	8
I know more about how to link mathematics and movement activities	37.50% 3	62.50% 5	0.00% 0	0.00% 0	0.00% 0	8
I am more likely to use drama or movement in teaching mathematics	37.50% 3	62.50% 5	0.00% 0	0.00% 0	0.00% 0	8
I am more able to turn mathematics into something to be shared through performance	37.50% 3	50.00% 4	0.00% 0	12.50% 1	0.00% 0	8
My idea of what maths is has changed from taking part in the project	12.50% 1	37.50% 3	25.00% 2	25.00% 2	0.00% 0	8

Teacher views of pupil responses

Teachers made many positive comments about pupil engagement. Open comments by a minority of teachers provided insight to more ambivalent responses to some questions, referring to some pupils finding GMAs difficult to engage with, or finding continual repetition off putting.

	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE	TOTAL
The group mastery activities were effective in helping my pupils learn mathematics	12.50% 1	62.50% 5	12.50% 1	12.50% 1	0.00% 0	8
The group mastery activities helped develop a sense of togetherness	50.00% 4	37.50% 3	12.50% 1	0.00% 0	0.00% 0	8
Pupils found it hard to do the group mastery activities	12.50% 1	62.50% 5	0.00% 0	25.00% 2	0.00% 0	8
The information provided and professional development activity was enough to be able to do the group mastery activities	62.50% 5	37.50% 3	0.00% 0	0.00% 0	0.00% 0	8
I found it hard to lead the group mastery activities	0.00% 0	12.50% 1	12.50% 1	37.50% 3	37.50% 3	8
I used the activities flexibly and adapted them to suit my class	25.00% 2	62.50% 5	12.50% 1	0.00% 0	0.00% 0	8

Using materials/activities in the future

	STRONGLY AGREE	AGREE	NEITHER AGREE OR DISAGREE	DISAGREE	STRONGLY DISAGREE	TOTAL
I would use the Embodying Maths activities with my class next year	25.00% 2	75.00% 6	0.00% 0	0.00% 0	0.00% 0	8
The project hasn't really influenced how I will teach in the future	0.00% 0	0.00% 0	0.00% 0	100.00% 8	0.00% 0	8
The project activities are a good way to learn mathematics	25.00% 2	50.00% 4	12.50% 1	12.50% 1	0.00% 0	8
I am not sure that it is worth spending time on the project activities	0.00% 0	0.00% 0	25.00% 2	50.00% 4	25.00% 2	8
I have or would use the same approaches in other subject	12.50% 1	62.50% 5	25.00% 2	0.00% 0	0.00% 0	8
I would recommend the project to other teachers	37.50% 3	37.50% 3	25.00% 2	0.00% 0	0.00% 0	8

Whilst most teachers were positive about activities and using them again, concerns expressed by a minority related to the challenge for their pupils, with a suggestion that this was more suitable for lower KS3 classes (presumably Y3 or Y4) than older KS2 children and the need for greater mathematical challenge.

Appendix 11- Sheffield 2016/17 and London 2017 pupil views on embodied activities

Table A11 Views on embodied activities London 2017

Statement		Strongly agree	Agree	Neither Agree nor disagree	Disagree	Strongly disagree	Total
I enjoyed going outside the classroom to do maths activities	n	93	56	34	7	3	193
	%	48.2	29.0	17.6	3.6	1.6	100.0
I did not like maths lessons where we did movement and maths together	n	18	10	52	44	67	191
	%	9.4	5.2	27.2	23.0	35.1	100.0
I liked doing the maths performance	n	63	35	44	24	20	186
	%	33.9	18.8	23.7	12.9	10.8	100.0
I got nervous in the maths lessons outside the classroom	n	9	12	37	50	78	186
	%	4.8	6.5	19.9	26.9	41.9	100.0
I did not like the activities in the classroom when we all did movements at the same time	n	16	11	43	53	64	187
	%	8.6	5.9	23.0	28.3	34.2	100.0
I liked it when Victoria and Shane did movement maths with us	n	87	29	35	16	22	189
	%	46.0	15.3	18.5	8.5	11.6	100.0

Table A11.2 Sheffield 2016/17 pupil views on embodied activities

Statement		Strongly agree	Agree	Neither Agree nor disagree	Disagree	Strongly disagree	Total
I enjoyed going outside the classroom to do maths activities	n	59	48	21	1	5	134
	%	44.0	35.8	15.7	0.7	3.7	100.0
I did not like maths lessons where we did movement and maths together	n	13	4	24	31	59	131
	%	9.9	3.1	18.3	23.7	45.0	100.0
I liked doing the maths performance	n	67	34	15	5	12	133
	%	50.4	25.6	11.3	3.8	9	100.0
I got nervous in the maths lessons outside the classroom	n	6	13	16	33	64	132
	%	4.5	9.8	12.1	25	48.5	100.0
I liked it when different teachers did movement maths with us	n	41	40	34	9	9	131
	%	30.8	30.1	25.6	25.0	6.8	100.0

Note where questions were left blank responses excluded for individual statements.

Appendix 12 Analysis of attitude to the project factors for London 2016/17 pupils

PCA with Varimax rotation

2 Factors with Eigen values over 1.

Rotated Component Matrix[a]

	Component	
	1	2
I enjoyed going outside the classroom to do maths activities	.507	.319
I did not like maths lessons where we did movement and maths together	.786	.151
I liked doing the maths performance	.784	-.035
I got nervous in the maths lessons outside the classroom	.010	.947
I did not like the activities in the classroom when we all did movements at the same time	.691	.338
I liked it when Victoria and Shane did movement maths with us	.741	-.108

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Only ' I got nervous in the maths lessons outside the classroom' loaded on Component two.

Appendix 13 Sheffield pre and post-test affect

Table A13.1 . Shows the total number of pupils (expressed as a %) that showed an increase, decrease, no change in affect and group work pre and post embodying maths intervention.

	AFFECT INCREASE		AFFECT DECREASE		AFFECT NO CHANGE		GROUP WORK INCREASE		GROUP WORK DECREASE		GROUP WORK NO CHANGE		COMPARISON NOT AVAILABLE		TOTAL
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n
SHEFFIELD LYDGATE	31	50.82	20	32.79	2	3.28	32	52.46	20	32.79	1	1.64	8	13.11	61
SHEFFIELD HUNTERS BAR	13	15.12	11	12.79	0	0.00	10	11.63	12	13.95	1	1.16	62	72.09	86
SHEFFIELD COMBINED	44	29.93	31	21.09	2	1.36	42	64.09	32	21.77	2	1.36	70	47.62	147
LONDON	102	24.58	95	22.89	19	4.58	99	75.71	100	24.10	17	4.10	199	47.95	415

Ranks

		N	Mean Rank	Sum of Ranks
AffectPOST - AffectPRE	Negative Ranks	31[a]	30.74	953.00
	Positive Ranks	44[b]	43.11	1897.00
	Ties	2[c]		
	Total	77		
GroupworkPOST - GroupworkPRE	Negative Ranks	32[d]	39.55	1265.50
	Positive Ranks	43[e]	36.85	1584.50
	Ties	2[f]		
	Total	77		

a. AffectPOST < AffectPRE

b. AffectPOST > AffectPRE

c. AffectPOST = AffectPRE

d. GroupworkPOST < GroupworkPRE

e. GroupworkPOST > GroupworkPRE

f. GroupworkPOST = GroupworkPRE

Test Statistics[a]

	AffectPOST - AffectPRE	GroupworkPOST - GroupworkPRE
Z	-2.494[b]	-.843[b]
Asymp. Sig. (2-tailed)	.013	.399

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

This indicates a significant change in the pre and post affect scores.

Appendix 14 Correlations between liking the project and mathematics and group affect (for Sheffield???)

Relationship between post-test maths affect and group working and overall project affect

Significant correlations:

	Overall project affect
Pre Affect	0.22, P<0.01
Post Affect	0.38, P<0.01
Pre Group work	0.22, P<0.01
Post group work	0.40, P<0.01

Seems to suggest that if you like maths before the project you will like the project?

Overall Project affect

Number of correlates between the questions.

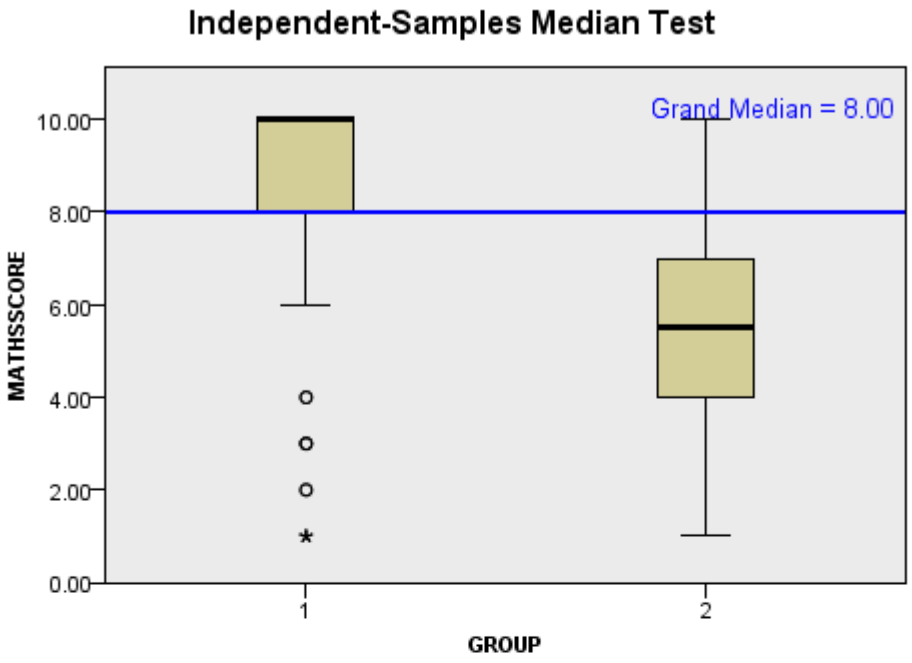
Correlations

			Enjoyed_goingoutside_classroom	Did_not_like_movement_lessons	Liked_doing_maths_performance	Nervous_in_lesson_outside_classroom	Didnot_like_joint_movement_classes	Liked_Victoria_Shane
	Affect	Correlation Coefficient	.034	.087	.084	.067	.034	.052
		Sig. (2-tailed)	.593	.171	.189	.293	.599	.411
		N	247	247	247	247	247	247
	Groupwork	Correlation Coefficient	.064	.135	.126	.085	.084	.161
		Sig. (2-tailed)	.319	.034	.048	.184	.189	.011
		N	247	247	247	247	247	247
	AffectPost	Correlation Coefficient	.184	.238	.233	.196	.176	.157
		Sig. (2-tailed)	.005	.000	.000	.003	.008	.018
		N	229	229	229	229	229	229
	Groupworkpost	Correlation Coefficient	.173	.222	.216	.024	.148	.312
		Sig. (2-tailed)	.009	.001	.001	.713	.025	.000

	N	229	229	229	229	229	229
Enjoyed_goingoutside_classroom	Correlation Coefficient	1.000	.732	.726	.651	.680	.709
	Sig. (2-tailed)	.	.000	.000	.000	.000	.000
	N	261	261	261	261	261	261
Did_not_like_movement_lessons	Correlation Coefficient	.732	1.000	.778	.659	.824	.775
	Sig. (2-tailed)	.000	.	.000	.000	.000	.000
	N	261	261	261	261	261	261
Liked_doing_maths_performance	Correlation Coefficient	.726	.778	1.000	.618	.750	.751
	Sig. (2-tailed)	.000	.000	.	.000	.000	.000
	N	261	261	261	261	261	261
Nervous_in_lesson_outside_classroom	Correlation Coefficient	.651	.659	.618	1.000	.701	.646

		Sig. (2-tailed)	.000	.000	.000	.	.000	.000
		N	261	261	261	261	261	261
	Didnot_like_joint_movement_classes	Correlation Coefficient	.680	.824	.750	.701	1.000	.741
		Sig. (2-tailed)	.000	.000	.000	.000	.	.000
		N	261	261	261	261	261	261
	Liked_Victoria_Shane	Correlation Coefficient	.709	.775	.751	.646	.741	1.000
		Sig. (2-tailed)	.000	.000	.000	.000	.000	.
		N	261	261	261	261	261	261

Appendix 15 Statistics for Sheffield test comparison post-test 2017 with 2016 cohort



Total N		219
Median		8.000
Test Statistic		64.919
Degrees of Freedom		1
Asymptotic Sig. (2-sided test)		.000
Yates's Continuity Correction	**Chi-Square**	62.676
	Degrees of Freedom	1
	Asymptotic Sig. (2-sided test)	.000

1. Multiple comparisons are not performed because there are less than three test fields.