RLC Research Review:
Maths Mastery and Feedback

Context – Looked After Children:

According to c. 41 of the Children Act 1989, Looked After Children (LAC) are children that have been in the care of a local authority and provided with accommodations for a continuous period of more than 24 hours. A child up is eligible for the LAC designation until they turn 18, return home, or are adopted (National Society for the Prevention of Cruelty to Children [NSPCC], 2021). The education of LAC in England is supported through key legislation and policy:

- The Children and Young Persons Act 2008, which amends aspects of the Children Act 1989 and reforms the care system of LAC,
- The Children and Families Act 2014, which specifies that local authorities must appoint at least one person to support the educational achievement of LAC, and
- Statutory guidance from the DfE (2021a), such as how to promote the emotional and behavioural development of LAC.

As of 31 March 2020, there were 80,080 LAC in England, representing nearly 1 in every 100 pupils attending school (DfE, 2021). While already a striking number, it has been growing year over year since 2008, increasing by over 15% since 2015. The majority of these children are placed in the care of their local authority due to abuse or neglect (63%), while the remaining are placed into care due to family dysfunction (14%), family in acute distress (8%), absent parenting (7%), child's disability (3%), parent's illness (3%), or other issues (2%) (DfE, 2021).

About 10% of LAC move between three or more placements each year, putting them at significant risk regarding their well-being and positive behavioural outcomes. Moreover, a large and growing body of evidence suggests that LAC may suffer from established behaviour patterns developed throughout early childhood that negatively impact their ability to thrive in typical educational settings without specific attention to their social-emotional and academic development. At the same time, LAC are far from a homogenous group of children. They vary by age (ranging from under 1 year up to 18 years), ethnicity, gender, reasons for being looked after, placements (e.g., foster placement, living independently), legal status (e.g., care order, voluntary agreement), locality of placement, and support needs.

The DfE's (2021) most recent data from 2019 on outcomes for LAC finds the following:

- four times more likely to have a special educational need;
- nine times more likely to have an education, health, and care plan;
- lower educational attainment non-looked after children at
  - key stage 1 in reading, writing, and mathematics, and science (26 percent fewer reached the expected standard);
  - key stage 2 in reading, writing, and mathematics (28 percent fewer reached the expected standard), though this outcome appears closely related to the prevalence of pupils with a special education need;
  - key stage 4 in the average Attainment 8 score (44.6 versus 19.1), percentage of pupils achieving grade 5 or above in English and mathematics (40.1 versus 7.2), and English baccalaureate average point score (3.87 versus 1.52).

In general, LAC are more likely than non-looked after children to have mental health issues, additional or special education needs, and lower educational attainment. Finally, after leaving care, they are also less likely to be in education, training, or employment (NSPCC, 2021). See the sources below for more in-depth examinations of the complex and multi-faceted circumstances and outcomes LAC face.

Department for Education. (2021). *Statistics: Looked-after children*. https://www.gov.uk/government/collections/statistics-looked-after-children

National Society for the Prevention of Cruelty to Children. (2021, August 6). *Statistics: Looked-after children*. https://www.gov.uk/government/collections/statistics-looked-after-children

Oakley, M., Miscampbell, G., & Gregorian, R. (2018). *Looked-after children: The silent crisis*. Social Market Foundation.
Sebba, J., Berridge, D., Luke, N., Fletcher, J., Bell, K., Strand, S., Thomas, S., Sinclair, I., & O'Higgins, A. (2015). *The educational progress of looked after children in England: Linking care and educational data*. Rees Centre, University of Bristol.

Title:

Key text:

Boyd, P., & Ash, A. (2018). Mastery mathematics: Changing teacher beliefs around in-class grouping and mindset. *Teaching and Teacher Education, 75*, 214–223. https://doi.org/10.1016/j.tate.2018.06.016

Other reading:

Boaler, J. (2016). *Mathematical mindsets*. Jossey-Bass.
Elliott, V., Baird, J.-A., Hopfenbeck, T. N., Ingram, J., Thompson, I., Usher, N., Zantout, M., Richardson, J., & Coleman, R. (2016). *A marked improvement? A review of the evidence on written marking*. Education Endowment Foundation.
Jerrim, J., & Vignoles, A. (2016). The link between East Asian "mastery" teaching methods and English children's mathematics skills. *Economics of Education Review, 50*, 29–44. https://doi.org/10.1016/j.econedurev.2015.11.003
National Centre for the Excellence in the Teaching of Mathematics. (n.d.). *Mastery explained: Evidence, exemplification and illustration to explain the mastery approach*.
See also: http://educationendowmentfoundation.org.uk (ongoing research on mastery learning and mathematics mastery, and improving mathematics)

Method:

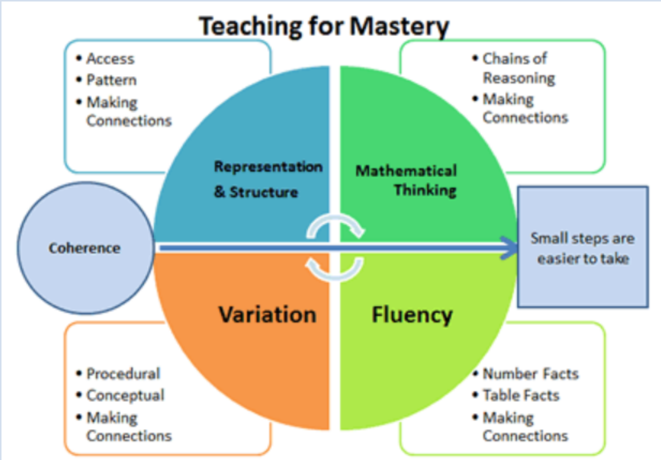
In the key text, Boyd and Ash (2018) present a study that examined the pedagogical beliefs of primary teachers in England as they implemented a maths mastery program. The article begins an in-depth review of the literature surrounding school maths, mastery approaches to learning and their relation to South Asian approaches, mindset theory and its relation to self-efficacy beliefs in maths, issues with grouping pupils based on prior attainment, and ongoing efforts to recontextualize school maths. After setting the stage for their study, the authors present the research design, which involved a collaborative effort between a university-based researcher, seven teacher researchers based in an alliance of different schools, and the school-based director of the schools alliance as a co-researcher. Over the course of two years, the seven teacher researchers implemented a mastery approach to teaching mathematics in their classrooms, with data collected via classroom video and semi-structured interviews with the teachers. Although the findings from this study are limited given its small-scale, qualitative design, its in-depth nature means that findings are likely to still hold general informative value.

The rest of the literature review below is taken from (a) individual journals (all peer reviewed) primarily in the area of education, (b) relevant evaluation reports commissioned by the Education Endowment Foundation (EEF), and (c) grey literature sources that evidenced a clear connection with the research literature and which contributed to current debates and understandings. Additionally, sources were selected to illustrate a range of aspects of the theory and a range of research methodologies from international contexts. All incorporated sources were published within the last ten years.

Overview of the Issue or Subject:

Maths mastery is an approach to teaching and learning in which the general progression through curriculum content is dependent on all pupils reaching a baseline level of "mastery." Unlike traditional teaching approaches where academically weaker pupils may fall behind or stronger pupils move ahead, the curriculum pace is kept constant but the depth of learning within each topic is allowed to vary. Such variation is made possible by segmenting learning within maths topics into *units*, each with clearly defined objectives. Depending on the source material or program, maths mastery might also be called *teaching for mastery* or a *mastery approach*, among other labels that incorporate the notion of mastery. However, the EEF recommends a degree of caution when drawing from such materials, as they may be referencing other approaches to maths teaching found in high-performing places in East Asia (e.g., Singapore), where mastery can take on a different character.

The National Centre for Excellence in the Teaching of Mathematics (NCETM) suggests that teaching for mastery can be broken down into five big ideas. Analysis of these big ideas reveals various connections with Carol Dweck's work on *growth mindset*, Jo Boaler's work on *mathematical mindsets*, and, more generally, the growing evidence base for the importance of feedback in learning processes. Where those connections are prominent in the sections that follow, they are discussed in brief.



Source: NCETM (2017)

Coherence

The maths mastery approach is grounded in the belief that all pupils can achieve success and develop a deep conceptual understanding of mathematics topics. Hence, a class moves together through curriculum content, maintaining a level of coherence. Typically, the minimum level of mastery that pupils are expected to demonstrate falls around 80%. In instances where a pupil demonstrates the expected level of mastery for a given topic, their work shifts to making deeper connections within the topic area and thus a more robust conceptual understanding. However, the learning of "key ideas," or foundational concepts, ensures all pupils can make the necessary steps towards future lessons. For pupils struggling in a given content area, additional supports (e.g., intensive teaching, tutoring) are provided until they achieve the expected level of mastery. Indeed, the empirical research suggests such supports are critical to mastery learning, as otherwise the approach does little to narrow disadvantage gaps. The EEF (XX) guidance report for improving mathematics the early years and Key Stage 1 detail the following targeted supports:

- use more experienced staff to support children with the greatest needs;
- provide training and support for staff using targeted activities, including structured resources or activity plans with clear objectives;
- sessions should be brief and regular;
- quality is generally more important than quantity— there is some evidence to suggest that time-limited interventions may be more effective;39 and
- make explicit connections between targeted support and everyday activities or teaching; practitioners delivering additional support should have time to discuss this work with their colleagues. (see p. 30)

Mastery learning further attends to the emerging consensus in the research literature that in-class grouping based on prior attainment primarily benefits pupils with higher levels of prior attainment while further disadvantaging those with lower levels. As Boaler discusses in relation to developing pupils' mathematical mindsets, "when students are grouped heterogeneously, there are different ways to encourage students to look at a problem. These include asking good questions, rephrasing problems explaining, using logic, justifying methods, using manipulatives, connecting ideas, and helping others" (122). Several of these suggestions, such as asking good questions, are discussed below.

Connected to the notion of growth mindset, an emphasis on coherence implies that teachers maintain an awareness for how pupils are developing their self-perception in maths topics. Boyd and Ash found that a mastery approach requires teachers to examine their beliefs about “becoming a mathematician, including adopting a more malleable conception of intelligence in the context of maths” (p. 221). Studies find that explicit teaching of the difference between growth and fixed mindsets as well as creating a classroom environment that displays growth mindset imagery appear to be promising strategies.

Boyd & Ash (2018) also found that planning maths mastery approaches requires additional emphasis on teachers’ maths subject knowledge. As they put it, students will be exploring the planned curriculum to different depths, bringing “the focus on exploring and on dialogue appears to keep the skill and subject knowledge of the teacher firmly at the heart of this mastery approach to maths” (p. 221).

Representation and Structure
Studies of maths mastery typically lend support to lesson structure that moves between whole class engagement around a contextualised problem and independent or collaborative work in which pupils develop their ability to talk about and reason with maths concepts. Within this structure, research suggests that teachers should place emphasis on developing pupils’ representational understanding and involve ample use of manipulatives:

- Manipulative: *an object that children or practitioners can interact with and move to represent mathematical ideas. Manipulatives could include everyday objects such as pine cones, buttons, and small toys as well as resources like interlocking cubes, Cuisenaire rods, Dienes blocks, and building blocks.*
- Representation: *a particular form in which mathematics is presented. Representations include informal drawings, mathematical symbols, and more formal diagrams, such as a number line or graph.* (Clark et al., 2020, p. 20)

The EEF’s Teaching and Learning Toolkit outlines a variety of effective practices for promoting pupils’ representational understanding of mathematics concepts grounded in the recent research literature (see page 21 of *Improving Mathematics in the Early Years and Key Stage 1*):

- Ensure that children understand the links between the manipulatives and the mathematical ideas they represent. For example, a child may be confident using Dienes blocks to add but be unable to connect this to a written addition. This requires practitioners to explicitly help children to link the materials (and the actions performed on or with them) to the mathematics of the situation. This should enable children to develop related mathematical images, representations, and symbols
- Ensure that there is a clear rationale for using a particular manipulative or representation to teach a specific mathematical concept. Practitioners should consider carefully how the manipulative will be used to build on existing understanding, and help develop increasingly sophisticated approaches and ideas.
- Encourage children to represent problems in their own way.36 Practitioners should support children to become familiar with a repertoire of strategies to use to represent mathematical ideas, including their fingers, drawings, and marks such as tallies and arrows. Children should be free to invent and explore their own representations to record their thinking and communicate their understanding
- Be aware that young children can be distracted by the surface features of a novelty manipulative—this can take away from the intended learning aim. Using a given manipulative regularly, or introducing it through play to gain familiarity can be beneficial.
- Use manipulatives and representations to encourage discussion about mathematics.33 Children can work in pairs and small groups using manipulatives to solve problems and to encourage questions about other children’s strategies and reasoning. This can prompt the sharing and comparison of different approaches. Manipulatives can also be used by children to communicate what they know.

Mathematical Thinking

Developing pupils' mathematical thinking ability is about ensuring they have opportunities to work with challenging maths problems that require reasoning, making connections with prior knowledge, and, in many cases, peer interaction. Studies suggest that a foundational element to mathematical thinking is helping students develop their use of mathematical language, enabling them to think about maths concepts flexibly and with greater self-efficacy. Similarly, Boaler's (2016) landmark work on mathematical mindsets suggests that teachers can better support their pupils by giving greater attention to *open math problems* (or rich mathematical tasks) that require creative solution strategies, involving different ways of seeing the problem, different solving methods, and different representations. Such open problems are distinguished from simple calculation-based problems, where it is often believed "faster is better," and should create opportunities for pupils to think about maths both numerically and visually. At the same time, pupils can struggle with open-ended problems if they have had limited opportunities to work with them in past experiences, particularly the lack of one correct solution strategy. Hence, Boaler suggests that teachers need to be intentional about creating ample learning opportunities with open math problems and cultivating pupils' mathematics self-efficacy. Boaler offers the following six questions that can guide the creation of such problems:

- Can you open the task to encourage multiple methods, pathways, and representations?
- Can you make it an inquiry task?
- Can you ask the problem before teaching the method?
- Can you add a visual component?
- Can you make it low floor and high ceiling?
- Can you add the requirement to convince and reason?

Fluency

Studies suggest that when pupils can work fluently with maths concepts, it can promote deeper understandings and reduce the need to revisit material. Although there is limited empirical support for having pupils memorise rote mathematical procedures, the available evidence is comparatively strong in support of their ability to recall particular facts, such as multiplication/division facts (e.g., multiplying by 10) and addition/subtraction facts (e.g., subtracting multiples of 10). When pupils have thorough knowledge of these facts, it can reduce the associated cognitive load of working through the mechanical operations of a problem, enabling them to redirect focus to the complex problem-solving skills required. However, there is limited empirical support that either procedural fluency or conceptual understanding should be prioritized, as both are critical to pupils' overall success in mathematics.

Boaler (2016) contends that math facts are best learned when pupils can use numbers in many different ways and in different problem scenarios. By contrast, there is little support for timed math tests, which can again convey the notion that "fast is better" when it comes to success in mathematics.

The EEF's guidance report for improving mathematics in Key Stages 2 and 3 notes that "Quick retrieval of number facts is important for success in mathematics. It is likely that pupils who have problems retrieving addition, subtraction, multiplication, and division facts, including number bonds and multiples, will have difficulty understanding and using mathematical concepts they encounter later on in their studies. . . . Pupils are able to apply procedures most effectively when they understand how the procedures work and in what circumstances they are useful." (p. 16)

Variation

The NCETM describes variation as a twofold consideration for teachers' planning. First, it involves teaching maths concepts in multiple ways to illustrate the underlying connections among key ideas and develop a more holistic understanding. For instance, when identifying geometric shapes, pupils need to see varied examples and non-examples, not just the typical polygons of each shape. Boaler (2016) notes how having pupils work exclusively with "perfect" examples can lead to misconceptions that go unnoticed.

Second, variation also involves the critical planning decisions to ensure mathematics content and activities are sequenced to enable all pupils to achieve higher levels of understanding. When giving feedback, for example, Carol Dweck's research on mindsets suggests that teachers should aim to cultivate a learning orientation in their pupils rather than a performance orientation, where the former signifies that they:

- believe effort leads to success
- believe in their own ability to improve and learn
- prefer challenging tasks
- define success at difficult tasks using their own criteria;
- talk themselves through something when confronted with a difficult task

Maths Mastery and Assessment
Regarding assessment within a mastery approach, the EEF Teaching and Learning Toolkit offers the following summary: "a number of aspects of mastery learning are similar to other contemporary approaches such as the use of initial diagnostic assessments like universal screening in Response to Intervention models (Mellard & Johnson, 2008). The use of formative assessments and tests to monitor pupils' progress systematically then give detailed feedback on what they need to do to close the gap between their current performance and the desired goal is similar to assessment for learning and feedback models (Black and Wiliam, 1998; Hattie & Timperley, 2007)."

Recent research shows that comment-only feedback is superior to grade- or mark-only feedback. Feedback needs to be 'informative and descriptive' and should help students show where they are in relation to the learning goals and give strategies and advice on how to bridge the gap. By contrast, marking is less helpful when it focuses on pupils' personal characteristics or their positional level relative to other children in the class. The latter reinforces a performance orientation and can lead to maladaptive learning strategies, such as avoiding practising or trying new learning approaches. Classroom studies by Ofsted into the marking of spelling and punctuation show that this aspect of literacy is corrected more in primary than Year 7 classrooms, but that the marking is often inconsistent, lacking in guidance for learning linked to the corrected mistake. Suggestions from research into marking show the possibility of links between marking correct answers (e.g., spelling) and formative assessment. This highlights giving children the opportunity to find their own mistakes, using clear guidance, and then correct them.

The Overall Strength of the Research Evidence
Overall, the extant evidence about the effectiveness of mastery learning suggest it tends to produce one of two outcomes: little or no impact, or up to about six months of additional progress. This discrepancy appears related to several factors:

- It appears critical to adopt a high level of mastery (80-90%) for pupils to attain before progressing in the curriculum. Studies indicate that lower levels of mastery may reproduce the attainment gap.
- Outcomes may be related to the specific population subgroups involved in an intervention. However, studies such as the evaluation of the Mathematics Mastery program funded by the Education Endowment Foundation found that it was largely unclear whether a mastery approach has a different impact on pupils eligible for free school meals, or on pupils with higher or lower attainment.

Options or Questions Regarding Key Issues and Debates:

What baseline understandings are we starting with about how children learn mathematics?

How are tasks and resources purposefully selected to ensure pupils are able to reach the expected level of mastery?

To what extent is classroom time dedicated for children to learn mathematics and integrate their understandings with other concepts throughout the day? Relatedly,

- How is mathematics vocabulary reinforced in other curriculum areas?
- What opportunities do children have for extended discussions of mathematical ideas?

How are manipulatives and representations incorporated into current teaching practices? Relatedly,

- What efforts are taken to ensure children see the connection between manipulatives and the mathematical ideas they represent?
- How are children encouraged to represent maths problems in their own ways?
- How are the connections among mathematical facts, procedures, and concepts addressed in maths lessons?

How are pupils' prior understandings of mathematics being built upon? Relatedly,

- What assessment methods are used to ascertain what pupils do and do not know, and how are the findings used extend the learning for all pupils?
- To what extent are teachers prepared to provide feedback that is specific and clear, encourages and supports further efforts, and is given sparingly.
- How are common misconceptions in mathematics concepts planned for before they arise?

What high-quality targeted supports are used to help all pupils learn mathematics? Relatedly,

- To what extent do we have a shared language for mastery learning?
- How does this connect with our behaviour and feedback policies?
- How are classroom groupings determined?

Potential Implementation Issues to Consider:

The EEF notes that effective implementation of mastery learning, including maths mastery, hinges on a number of factors.

- Effective diagnostic assessment to identify areas of strength and weakness,
- Carefully sequencing topics so that they gradually build on foundational knowledge,
- Flexibility for teachers on how long they need to spend on any particular topic,
- Monitoring of pupil learning and regular feedback so that pupils can master topics prior to moving to the next, and
- Additional support for pupils that struggle to master topic areas.

Additionally, for some maths topics and circumstances, schools and teachers may decide that a mastery approach is inappropriate. In these instances, it may be reasonable to reduce the time allotted to mastery learning to half a term; however, there currently exists very little evidence about the effectiveness of maths mastery on short timescales. Caution should be exercised that implementation fidelity is preserved.

Finally, returning to the topic of marking and how it might optimally take form within a maths mastery program, Elliott et al. (2016) suggest that schools and researchers will need to give attention to the following areas:

- The long-term impacts of marking policies that eschew grades for a focus on formative comments,
- How class time can be effectively utilized when it comes to pupils responding to marking, and
- Balancing and comparing the relative influences of selective marking that focuses on particular aspects of work with more thorough approaches.