

Mixed-Age Teaching and Mastery Approaches to Mathematics

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Abstract

Internationally, schools with small numbers of children and constrained funding are not able to group the children in classes based on their age. Rather, the children are combined into larger 'mixed-age' classes. Schools and teachers manage this situation in different ways, for example by teaching the class as two or more separate age-based groups within the classroom, or by 'mixed-age' teaching of the whole class together. All teachers face the challenge of diversity within their class of learners but arguably this is exacerbated for teachers of mixed age classes. In England, this issue of mixed age teaching has been foregrounded during current efforts to reform the teaching of mathematics, where a national policy is focused on developing 'teaching for mastery'. The characteristics of mastery approaches to teaching mathematics are contested and there is considerable variation between schemes and schools. Mastery approaches developed in England have been influenced to different degrees by practice in East Asian nations including Singapore, Shanghai, and Japan, which have all, with their varied contexts and approaches, seen success in international comparative tests. This paper provides a selective review of international research into mixed-age teaching, judging the current evidence to be of some use but insufficient, and positions the findings in relation to key characteristics of mastery approaches to teaching mathematics. Three generally agreed characteristics of mastery approaches to teaching mathematics, expectations of success for all pupils, in-depth sustained study of topics, and whole class teaching, appear to offer opportunities as well as additional challenges for teachers of mixed-age classes.

Keywords

Mixed-age; Mastery; Whole-class; Diversity; Collaborative learning.

Introduction

Many schools, internationally, teach children in mixed-age classes, through pedagogical choice or economic necessity. All classes include a diversity of students, but arguably mixed-age classes extend this diversity due to age related development. In England, children generally begin school by joining and remaining in an age-related year group, with some children in the class born in September but others, born in August, almost a year younger. Clearly, even this 'normal' class includes a diversity of pupils, including a twelve-month spread of ages. The age spread is doubled when considering two age-related groups joined into one mixed-age class. The focus on age of children is important because curriculum documents, textbook schemes and national tests become centred on this structural aspect of schooling. For example, in England, teachers are accountable for aligning children's progress to the national curriculum, which has expectations of content and learning set out in age-related year group stages.

At its heart, aiming to inform further research and classroom practice especially in teaching mathematics, this paper presents a selective review of international research into mixed-age teaching. However, in England and internationally, current efforts to reform the teaching of mathematics are influenced by East Asian practice and broadly focused on 'mastery' approaches (NCETM, 2016a). Three key characteristics, arguably common to the range of contested mastery approaches to teaching

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mathematics, appear to present some opportunities as well as additional challenges for teachers with mixed age classes. The next section introduces these key features of mastery approaches to teaching mathematics before the literature review on mixed-age teaching is presented in the main body of the paper. Finally, this leads to discussion of how the research evidence on mixed-age teaching relates to the development of mastery approaches to teaching mathematics.

Mastery Approaches to Teaching Mathematics

The revised national curriculum in England introduced in 2014 represented an attempt to shift towards a ‘knowledge-rich’ curriculum (DfE, 2014). In mathematics the introduction of the revised curriculum was accompanied by a significant policy shift to develop ‘mastery’ approaches to teaching mathematics (Blausten, Gyngell, Aichmayr and Spengler, 2020). Mastery approaches to teaching set constant learning outcomes for the whole class but allows time for all students to become proficient before moving on to new material. There is some experimental research evidence support for the impact of mastery approaches on learning, especially where students work collaboratively rather than at their own pace (EEF, 2018). There is some research evidence of mastery approaches in mathematics having a modest impact on attainment in primary schools (EEF, 2019). The implementation of mastery approaches to teaching mathematics in England has been supported by a national network of regional ‘maths hubs’ with online resources, professional development workshops and consultants working with groups of collaborating lead teachers based in schools that choose to participate (NCETM, 2014). As part of the ‘teaching for mastery’ development, the department for education in England has given official criteria-based approval of a small number of text-book schemes for teaching mastery approaches to mathematics (DfE, 2020). The NCETM conception of mastery approaches to teaching mathematics has been influenced by practice in East Asia, including Shanghai, Singapore, Hong Kong and Japan. This has included teacher exchanges, especially in a large project with Shanghai, with visits by teachers from England to China and masterclass demonstrations by visiting expert teachers from Shanghai. Evaluation of this exchange project has shown considerable variation in implementation of a ‘mastery approach’ in classrooms in England and has not demonstrated a strong impact on attainment (Boylan et al., 2019).

It is worth focusing, at least briefly, on the concept of ‘mastery’ before considering the characteristics of mastery approaches to teaching mathematics. A key idea is that ‘all children need a deep understanding of the mathematics they are learning, so that future mathematical learning is based on solid foundations which do not need to be re-taught’ with an aim that; ‘gaps in attainment are narrowed whilst the attainment of all is raised’ (Askew et al. 2015). Consider a secondary school pupil who has ‘mastered’ Pythagoras’ Theorem, this learner might be expected to: Find the length of the hypotenuse, given the lengths of the other two sides; find the length of one of the two shorter sides; apply the theorem to find missing lengths in three dimensional situations; apply the theorem in area and volume problems; recognise when the theorem might be usefully applied, even when it is not named; and prove the theorem (Drury 2018: 4). It is worth noting in this concrete example from Helen Drury, that three of the expectations of mastery concern application to problem-solving, including tackling new problems in unfamiliar situations. The definition of mastery approaches to teaching mathematics is a contested area and the NCETM ‘definition’ is broad, flexible, and open to varied interpretation by consultants, head teachers, teachers, and school inspectors (NCETM, 2016a; NAMA, 2015). The NCETM framework for ‘teaching for mastery’ includes five key ideas: coherence; representation and structure; mathematical thinking; variation; and fluency (NCETM, 2016b). Although NCETM claims to be informed by practice in East Asia, teaching mathematics in Shanghai is in some ways comparable but also has significant differences to approaches in Singapore (Jain, 2020).

At least three features of mastery approaches, seem to be generally agreed across the NCETM and across practice in South Asia. First, there is an underpinning assumption by the school and teacher that virtually all the students can be successful in learning mathematics. This has some challenges for

culturally held beliefs around mathematics in England (Boyd and Ash, 2018). Second, mastery approaches to teaching mathematics adopt in-depth study of a topic, rather than quickly moving on to new material, and a coherent sequence of lessons so that students make progress through small steps. It means that all the students are required to reach mastery before going on to the next lesson, even if a small number of them require some additional support intervention between mathematics lessons. Third, there is an implicit expectation in mastery approaches that whole-class teaching will be widely adopted, because the taught content will be common for all students in the class:

Taking a mastery approach, differentiation occurs in the support and intervention provided to different pupils... There is no differentiation in content taught, but the questioning and scaffolding individual pupils receive in class as they work through problems will differ, with higher attainers challenged through more demanding problems which deepen their knowledge of the same content

(NCETM, 2014:3).

This emphasis on whole class teaching had been a significant element of a previous government national reform policy in England that strongly influenced the teaching of mathematics through the 'national numeracy hour' (DfE, 2011). Effective whole class teaching, as an element of teaching for mastery, challenges previously established classroom practices in England such as differentiation by task and in-class grouping based on prior attainment (Boyd and Ash, 2018).

These three key features of mastery approaches to teaching mathematics: expectations for all to succeed; in-depth study of a topic; and emphasis on whole-class teaching; represent a considerable challenge to many primary teachers in England, not least because of the diversity of prior attainment in mathematics of pupils within their classroom. However, the three features appear to present challenges but also opportunities for those primary teachers with mixed age classes, because they arguably face an even wider diversity of learners in relation to prior attainment and because curriculum and teaching materials are often designed for age-based classes. The NCETM has developed some support for mixed age teaching in response to requests, especially from small schools, who are engaging with mastery approaches to mathematics but have to manage mixed-age classes (NCETM, 2020; Trundle et al., 2016).

Mixed-Age Teaching

Mixed-age teaching is an extension of pedagogical practices in response to having a class that usually includes two age groups and sometimes more. Mixed-age teaching means teaching that class as a single group of pupils, focusing on the same topic, and broadly learning together. It may therefore be distinguished from 'multi-age' (often referred to as 'multi-grade') teaching where the teacher creates age-based groups of pupils within the classroom, moving between these groups to teach and set tasks, and where only limited learning activities are shared across the age-based groups (Cornish 2006; Hoffman 2003; Smit and Engeli, 2015). Some of the published research does not distinguish sufficiently between these different definitions of mixed-age versus multi-age and so is of limited value (Hoffman, 2003). This issue of terminology created significant challenges in using key words to search for relevant research and it is important to note that the review presented in this paper is selective rather than comprehensive.

Teachers of mixed age classes face the challenge of responding to the wide diversity of learners within their classroom. Effective strategies developed for mixed-age teaching may therefore be inclusive and also useful for age-based classes. In drawing conclusions from four studies of mixed-age teaching, Smit, Hry-Belhammer and Raggl (2015) focus on teaching that takes advantage of mixed-age heterogeneity to enhance learning. They consider such teaching to be a form of teaching 'adaptively', meaning teachers are responsive and form flexible groups and respond promptly to address student

differences related to learning (Corno, 2008). Adopting a sociocultural perspective which links the teacher's curriculum subject knowledge, pedagogical knowledge and knowledge of the students, Corno rejects 'teaching to the middle' but also rejects the workload heavy multi-age teaching of several groups with differentiated tasks. In their place she develops the idea of the 'teaching ground', a common and dynamic centre which the teacher expands to include more learners over time (Corno, 2008). Adaptive teachers use flexible within-class grouping but based on frequent low stakes formative assessment rather than increasing the amount of summative assessment. These adaptive teachers identify subgroups of students with different needs through continual monitoring and respond with appropriate support but are continually aiming to withdraw support as students develop as self-regulated learners (Corno, 2008). This is an important possibility of investigating mixed-age teaching, that it may be a matter of pursuing effective teaching for diverse students and might be informed by teaching strategies that aim to use student diversity as an opportunity.

Mixed-age teaching is widespread and has been estimated in one study to affect up to 25% of pupils in relatively densely populated England and 40% in the more challenging geography and population distribution of Australia (Little, 2004). In developing economies with declining rural populations, the extent of mixed-age teaching is often difficult to ascertain but some estimates include 78% for Peru (in 1998) and 63% in Sri Lanka (in 1999) (Little, 2004). In India in 1996 84% of primary schools had 3 teachers or fewer and yet had 5 year groups so a considerable proportion of mixed age teaching seems likely. In Nepal in 1998 the number of teachers per primary school was 3.8 with 5 year groups to teach and so again there seems to be a high proportion of mixed-age teaching (Little, 2004). These estimates suggest that there is a strong social justice imperative for researchers and teachers to develop and share understanding of effective teaching for mixed-age teaching.

Impact on learning

There has been a long-standing debate about the impact of mixed age teaching on learning and on learners. The impact on learning, generally using test results as a proxy measure, has rumbled on since 1996 when two independently completed literature reviews identified no difference or a slightly negative influence of mixed-age teaching (Veenman, 1996). Even a recent attempt to complete a research meta-review on the impact of classroom practices related to mixed-age teaching have relied on old research reviews going back to the 1990s, for example on in-class attainment grouping (EEF, 2020). A recent study in Ireland, where about one third of 9 year olds are taught in mixed age classes, due to the large number of small rural schools, showed only minor differences in overall attainment but highlighted some gender differences with girls gaining lower scores in tests than boys within mixed-age settings (Quail and Smythe, 2014). This study suggests that teachers in mixed-age classrooms need to work particularly hard on engagement, interaction, discipline, and feedback, to acknowledge the gender dynamics and avoid potentially negative impact on girls' self-efficacy and progress. A quantitative study of 'combination classes' in California attempted to control the variables of school, teacher and students and found little or no impact on student attainment of having been in a combination class (Thomas, 2009).

It is worth considering what large-scale randomised control trial evidence might tell us in relation to mixed-age teaching. However, a key requirement of a randomised control trial is that the intervention is clear and well-developed, so that it is applied with fidelity by teachers (Wyse and Torgerson, 2017). The complexity of the classroom, especially in relation to a pedagogical approach for mixed-age teaching, makes this requirement particularly challenging. This becomes even more of a challenge when considering research meta-review evidence based on effect sizes because not only is effect size only partially related to the impact of the intervention but also because: '...when comparing studies, relative effect size can be a proxy for the relative effectiveness of interventions only in the highly restricted circumstances where all other factors impacting on effect size are equal' (Simpson, 2018: 898). Despite these considerable limitations, it is worth considering meta-review evidence related to

mixed-age teaching including for example meta-review reports on collaborative learning, on peer tutoring, on individualised instruction and on in-class grouping by prior attainment (EEF, 2020).

In terms of collaborative learning, meta-review evidence suggests a positive impact on learning, but the impact varies and is strongest when there are structured approaches with well-designed tasks (EEF, 2020). Some studies show collaborative learning strengthening the impact of strategies such as mastery approaches to learning. In relation to peer tutoring, again the meta-review evidence suggests a positive impact especially where structured approaches support the quality of peer interaction such as well-developed reading or mathematics schemes (EEF, 2020). However, two recent studies in England found little or no impact and some of the evidence on peer tutoring suggests that the impact is highest when it is used to supplement normal teaching, so that the peer tutoring is a form of consolidation. This idea of an intervention as a supplement to normal teaching is also raised in meta-review evidence on individualised learning approaches (EEF, 2020). There is some evidence of positive impact from individualised approaches, but the impact varies considerably between different schemes. The meta-review evidence on in-class grouping by prior attainment specifically does not include grouping by attainment across age groups because it is 'less commonly used' (EEF, 2020). The use of within-class grouping by prior attainment is considered to have a modest positive impact, although not so much for lower attaining students, and it comes with a warning from the wider body of research on setting that it may damage confidence and self-efficacy of these learners in the longer term.

Overall, there is limited and conflicting evidence on the impact of mixed-age teaching on learning, with many small studies foregrounding the positive effects and no large-scale randomised control trial evidence directly focused on mixed-age teaching available nor perhaps feasible. This is a challenging situation given the prevalence of mixed-age and multi-age teaching within education systems. At least this means that if teachers choose to use mixed-age teaching they are not pushing against a strong contradictory evidence base about its impact on learning outcomes.

Teacher strategies

The research into mixed-age teaching includes studies that focus on teachers' classroom strategies. From their consideration of the literature, Smit and Engeli usefully identify 7 central elements of mixed-age teaching as shown in Table 1. (2015). However, although publishing their paper in 2015, these authors relied on research dated from 1998 to 2007 in order to compile this list and so it must be considered somewhat dated (Smit and Engeli, 2015:138)

Table 1. Strategies for mixed-age teaching identified from the literature by Smit & Engeli (2015).

- | |
|---|
| <ul style="list-style-type: none"> (1) The teacher's role: Teacher is a facilitator and a coach, in addition to being an instructor (2) Differentiated instruction: Learners in each age group engage in learning tasks appropriate to their level of learning (3) Socially collaborative classroom: Supportive classroom climate; students help each other and collaborate flexibly (4) Flexible grouping: Learning is flexibly organized in the whole class and includes teacher-led groups, individuals within groups, collaborative groups, and individuals (5) General learning topic: The same general topic/theme in the same subject is covered for all learners (6) The quality of the learning tasks: The learning tasks are more open-ended, explorative, and problem-oriented (7) Formative assessment: To observe and diagnose how a learner is learning and is intended to improve teaching and learning |
|---|

Considering this list numbers 1, 3 and 7 appear to be relevant to any classroom but clearly could be significant in mixed-age teaching. Number 2 appears to be multi-age teaching. Numbers 4, 5 and 6 seem to be compatible with key characteristics of mastery approaches. The model developed by Smit and Engeli focuses around flexible grouping and social competence. It proposes a complex combination of differentiation by task, by support and by outcome depending on the topic and on the teacher's identification of good quality learning activities suitable for each year group or that were suitably open-ended to engage the learners across all year groups. The study was based on a teacher questionnaire with more than 200 items and surprisingly the 'role of the teacher' was dropped from the final model.

The design of the Smit and Engeli questionnaire was influenced by the study by Hoffman which was a qualitative multiple case study of four mixed-age teachers of 8 to 11-year-old students who had been identified as 'excellent mixed-age teachers by their principals' (2003). It is important to note that in these schools multi-age teaching was a positive choice made by the school in collaboration with teachers and parents. This distinctive context for this study potentially creates a positive orientation towards mixed age teaching and contrasts considerably with small rural schools where mixed age teaching may be viewed as a more of necessity due simply to the staff to pupil ratio. Hoffman's study informed the list of strategies in Figure 1 but importantly considered the context of the schools and the background of the teachers. Three of the teachers had special school experience and this may have influenced their commitment to focusing on individual learners and to curriculum making. All the teachers had experience of team teaching. This study by Hoffman did not explicitly consider the issue of teacher workload in pointing out that these empowered teachers were committed to mixed-age teaching and might not welcome mandated curriculum materials (2003).

A study of 35 teachers in California who had recently had to shift to teaching a mixed age class showed that the majority (24) used a mix of grouping, sometimes two groups by age (typically for maths and English) and sometimes other groupings (Mason and Burns, 2001). A minority (7) used whole class teaching throughout and just 4 used whole class plus grouping for some of the time. Teachers using whole class approaches emphasised problem-solving that allowed in-depth investigation by upper year group students. The study was in line with other studies within a context of mixed age teaching being imposed as a pragmatic solution to low student enrolment, the majority of teachers preferred single age teaching (27) although some gave a mixed response (4) and just 5 teachers, including 4 who were very experienced practitioners, expressed a preference for mixed age teaching. Teachers in this study identified some advantages of mixed age teaching for students but complained of additional teacher workload.

In a study of 30 small rural schools in Austria and Switzerland, including interviews with head teachers, teachers, and students, four broad approaches to mixed-age teaching were identified (Raggl, 2015):

- (1) Teaching-centred and age-oriented practices
- (2) Teacher-centred and age-oriented practices in combination with more pupil-centred methods
- (3) Whole class teaching
- (4) Individualised learning

Here we see that approaches 1 and 2 are forms of multi-age teaching. The study showed considerable variation in practice and the significance of context, including class size. The issue of high teacher workload was raised by teachers in this study. Some argued that the workload is similar but differently distributed compared to teaching an age-based class, with mixed-age teaching seeming to them to involve more planning and less marking.

In a useful but small-scale study of five small schools in Austria and Finland a broad distinction was identified between mixed-age teacher strategies that aim to reduce the effect of students' heterogeneity or alternatively strategies that capitalize on students' heterogeneity (Hyry-Beihammer and Hascher, 2015). The study developed a framework building on work by Kalaoja (2006) and Cornish (2006b):

1. **parallel curriculum:** students share the same themes or subjects but study the syllabus of their grade (year group); each grade (year group) is taught in turn
2. **curriculum rotation:** an entire class studies the curriculum of one grade (year group) for one year; in the next school year, they follow the syllabus of the other grade (year group); grades (year groups) are taught together
3. **curriculum alignment and spiral curriculum:** similar topics are identified in different grade curricula; students share the same themes or subjects; the basic concepts or ideas that are taught in the lower grades (year groups) are deepened and expanded on in the upper grades (year groups)
4. **subject stagger:** grades (year groups) study different subjects; each grade (year group) is taught in turn
5. **whole-class teaching:** grades (year groups) study and are taught the same subject at the same time and use the same material

Again, in this list the cross-over between mixed-age and multi-age teaching is apparent, with number 1 and 4 being multi-age whereas numbers 2, 3 and 5 could be part of mixed-age teaching. The strategies for reducing or overcoming the heterogeneity of students as much as possible were considered in this study to use practices such as parallel curricula, curriculum rotation, and whole-class teaching. In this case: 'The teacher either teaches one heterogeneous group, with the same teaching content and assignments for all students, or works with an age homogeneous group while the other group (or groups) works silently on their own assignments' (Hyry-Beihammer and Hascher, 2015:110). The alternative approach, which the researchers consider to be optimal, uses practices that: 'capitalize on the heterogeneity of the students but also reduce teaching demands, such as peer tutoring, personal work plans, or free work' (Ibid, 2015:110). This second approach the authors consider to be optimal for several reasons but including that it assumes heterogeneity is normal and they argue that 'the search for homogeneity is a false friend for instruction' (Ibid, 2015:110). In both strategies the researchers found that teachers also use different forms of differentiation and individualised learning guides.

A study focusing on differentiated task teaching in small schools in rural Switzerland found that only a few teachers were using differentiated instruction, multi-age teaching, on a daily basis (Smit and Humpert, 2012). This seems unsurprising given the workload implications of preparing a range of different tasks at different levels for each lesson. This study highlighted the need for inter-school networks and collaboration because of the isolation of teachers in small and rural schools. An innovative approach to task differentiated teaching in mixed age classes, often including up to five year groups, was developed in small rural schools in Colombia as 'Escuela Nueva' and has been exported and developed locally to many nations (Le, 2018). Broadly, the approach combines study based on self-instructional texts with group work. Lack of textbooks and lack of associated teacher training has hindered the development of this approach in Colombia and it has been interpreted and developed differently when exported to different nations, in some cases simply being seen as 'another textbook scheme'.

A recent project in the south of England used lesson study to consider the development of mixed-age and multi-age teaching within the context of developing mastery approaches across 17 teachers in 11 schools (Trundley et al., 2016). One of the teachers had three age groups of children in the class and avoided mixed-age teaching altogether. However, most of the teachers, with just two year groups

combined into one mixed age class, found that: ‘the curriculum is closely matched and it is often possible to start with the class together and then attend to the specific year group objectives through a number of different strategies including questioning, the use of different numbers in tasks and the use of rich tasks with different expectations related to outcomes’ (2016 p3). As in previous research, this study found it difficult to distinguish between multi-age and mixed-age teaching, not least because practice in schools tended to blur the boundaries between them. However, many of the teachers did, at least in some topics and lessons, use ‘low threshold, high ceiling’ open-ended tasks as a basis for mixed-age teaching (Boaler, 2016). The study report provides helpful vignettes of different approaches to lessons by individual teachers and overall gives some insight into the ways that small schools in England are currently managing mixed age classes in mathematics (Trundle et al., 2016). Overall, the research on teacher strategies seems to have struggled even to describe the practice of teachers in different contexts. It is complex, because there seems to be a variation in the practices of teachers from one classroom to another but also perhaps from one lesson to the next. In relation to the three key characteristics of mastery approaches to teaching mathematics, the research on teacher strategies suggests that some mixed-age teaching practice uses whole class teaching at least some of the time, but it tells us little about expectations for all pupils or in-depth study of topics.

Classroom learning environment

Having considered teacher strategies, it is also important to consider the development of culture or learning environment within a mixed-age class. This section will consider selected studies to illustrate the issues rather than to suggest that they represent a body of evidence with a consensus on key findings.

In a small-scale qualitative study including parents’ views of a single case study mixed age class and teacher, the potential benefits of mixed age classroom culture or learning environment are highlighted (Aina, 2001). The context of this study is that the mixed age class was formed at short notice to resolve lack of staffing and pupil enrolment at the start of the new school year, so the teacher did not have any specific professional development in relation to mixed age teaching. Based on conversations with parents of young children in a mixed age setting, as well as classroom observation and interviewing the teacher, this small-scale study suggested that the mixed age classroom ‘allows for each child to progress at their own pace’ and avoids labelling based on prior attainment. The teacher became ‘more creative’ in introducing topics to the whole class of 21 children and then grouping in various ways for completion of learning activities (Aina, 2001). This study seems interesting because it suggests that mixed-age teaching might create classroom learning environments that encourage learners to develop mastery oriented goals rather than performance related goals, so that they are focused on learning rather than competing with peers (Dweck, 2017; Boaler, 2016; Blackwell, Trzesniewski and Dweck, 2007; Grant and Dweck, 2003; Hart, Dixon, Drummond and McIntyre, 2004).

Somewhat in contrast to Aina’s findings, a synthesis of two ethnographic studies, set within a policy context in Germany of systematic shift to mixed age teaching in the early years of primary school, problematizes the view that mixed age classroom cultures might support autonomy and peer support (Huf and Raggl, 2015). In their analysis Huf and Raggl argue that the culture established by the teacher and institution is interwoven with the social orders of the peer culture (Corsaro, 2005) and that claims for increased learner autonomy and peer support at least deserve further investigation. They found in mixed age classrooms that ‘the older children act out dominance and authority over younger children’ (Huf and Raggl, 2015:239) so that the teacher’s authority is played out within the peer culture and mixed-age teaching therefore increased children’s control over each other. They argue that rather than distributing power within the classroom mixed age teaching in their study emphasised the teacher’s influence. These findings are provocative and deserve some consideration when considering collaborative and independent working in mixed age classes. It seems important to note that the

teacher's beliefs about the nature of mathematics and their expectations for all of their students will have an important influence on their pedagogy and on the culture of the classroom (Boaler, 2016). These studies indicate that the classroom culture in mixed-age teaching is problematic and under-researched. Individual teachers may be able to create a mixed-age classroom culture that avoids labelling children, but on the other hand children may adopt and reinforce aspects of the teacher's authority with unintended consequences. Classroom culture in mastery approaches to teaching mathematics seems to be a critical element in communicating the underpinning assumption that all virtually all the pupils can succeed and the teachers high expectations for all (Boyd and Ash 2018).

Discussion

Effective teaching is a complex human and relational activity which encompasses values and the purposes of education and so defies easy 'evidence-based' prescriptions from a body of empirical research. Even on this basis of modest expectations, the current international research on mixed-age teaching seems surprisingly insufficient as a basis for informing classroom practice. Given the arguably wider diversity of pupils within a mixed-age classroom, it may be more productive for teachers to critically engage with the research on teaching mathematics for diverse learners, and to pursue professional inquiry or practitioner research, rather than relying too much on the currently limited research specifically focused on mixed-age teaching. This assessment of the current situation of course also sets a challenge to educational researchers.

A common feature of mastery approaches to teaching mathematics is an underpinning assumption by the teacher that virtually all your students can be successful. This is a challenge for teachers in England, but it requires an additional stretch of beliefs and judgment for those teaching mixed-age classes. This is not least because national level policy, such as national curriculum documents, as well as textbook schemes, tend to reinforce age-related expectations of content and mastery. Teachers of mixed-age classes appear to be constantly managing a tension between the diversity of pupils in their class and age-based expectations set by policy and available teaching resources. There is insufficient research into the demands on teachers' mathematical knowledge of planning for mixed-age classes and for teaching in a mixed-age classroom. A common feature of mastery approaches to teaching mathematics is in-depth study of a topic before moving on to new material. This appears to offer some opportunities, as well as challenges, for mixed-age teaching. There is insufficient research into curriculum design for mixed-age teaching, including the planning of topics and lesson sequences. A common feature of mastery approaches is an emphasis on whole class teaching, although there are significant variations within this, for example between approaches influenced by practice in Shanghai or in Singapore. Whole class teaching is a challenge for teaching mixed age classes and understandably perhaps may lead many schools to use teaching assistants and other staffing strategies to avoid teaching the whole of a mixed-age class as one group. There is insufficient descriptive research of practice in schools to know how many schools in different national contexts adopt this multi-age teaching approach. However, gathering such data will not be as simple as it may seem, because of the complexity of schools and classrooms and because of variation in approaches to mixed-age teaching and in mastery approaches to mathematics. It is probably worth adopting the distinction between mixed-age and multi-age teaching as a starting point, but it will be important to acknowledge that some teachers may shift between these two broad approaches within a lesson or a sequence of lessons. There are significant additional issues entangled with the development of mastery approaches to mathematics that have not been seriously addressed within the current research on mixed age classes. These include teacher workload, the adoption of textbook schemes, and primary teacher subject knowledge for teaching mathematics.

Mixed-age teaching, or at least teaching in mixed age classes, appears to be widespread internationally. Reform efforts focused on developing mastery approaches to teaching mathematics appear to have created additional challenges but also some opportunities for teachers of mixed-age

classes. Teachers with mixed age classes engage with the age-based structure of curriculum documents, textbooks and other teaching resources, and this appears to make considerable demands on their knowledge for teaching mathematics. The issue of mixed-age teaching, in mathematics and other curriculum subjects, is not merely a technical matter, it has significant implications for social justice in education because it is so strongly linked to teaching for diversity. The current situation, in England and internationally, demands both further research and increased support for teachers through professional development and mixed-age friendly teaching resources.

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