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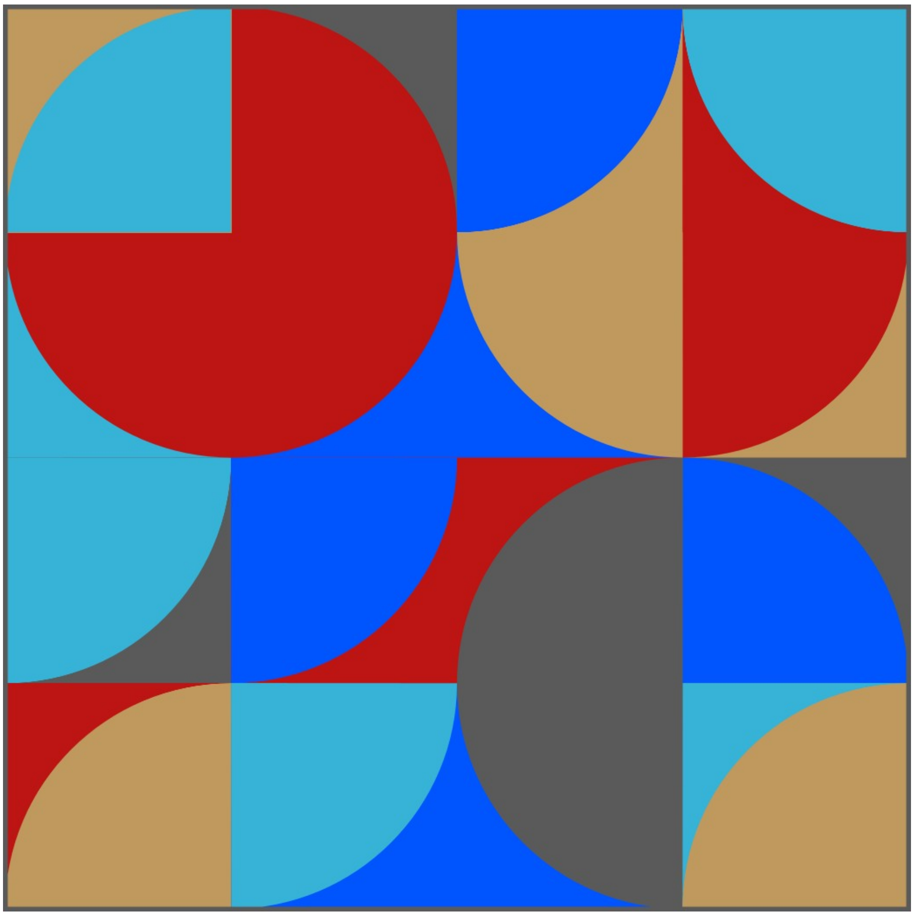
Mathematics learning and teaching in lower secondary schools in the UK

Report of a Joint Mathematical Council working group



Preface

The Joint Mathematical Council in 2025 established a working group to explore mathematics teaching in lower secondary schools across the four UK nations. The group examined the available evidence on mathematics teaching and learning relevant to the UK context.

The membership of the working group was chosen to reflect the many different interests and contexts, including teachers, teacher educators and researchers.

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The working group wishes to record its thanks to those additional people who contributed to the group’s work by identifying evidence sources, policy documents or acting as ‘readers’, including the JMC trustees.

Mathematics learning and teaching in lower secondary schools in the UK

Executive summary

1) Lower secondary school is a crucial point in students’ experiences of learning mathematics.
2) During lower secondary school, progress in mathematics slows for many students, and fewer students have positive attitudes towards mathematics. Evidence across the UK shows a decline in both the enjoyment of mathematics and students' confidence in mathematics.
3) Attainment gaps related to gender, socioeconomic background and other student characteristics widen during lower secondary school, as do gender differences in attitudes related to mathematics.
4) Mathematics teaching varies considerably during lower secondary school, and teachers are often less experienced and, in some parts of the UK, less qualified than those teaching older students. This variation can limit the impact of interventions and may also interact with the growing attainment gaps between different groups of students.
5) Mathematics curricula across the four UK nations all emphasise fluency, reasoning and problem solving. However, the experienced curriculum can be uneven, with a greater emphasis on number for some groups of students and less focus on geometry.
6) There is a wealth of resources and guidance available to mathematics teachers, many of which are high-quality and can support effective mathematics teaching. However, different organisations and resources use terms like problem solving in different ways. This can be confusing for mathematics teachers, can limit professional discussions, and can limit the implementation of evidence-informed pedagogies and practices.

Key Recommendations

1) Mathematics teaching and learning in lower secondary school needs to be a specific policy focus, including initiatives to support the monitoring of transition into lower secondary school mathematics.
2) Moves towards a shared language for key terms such as problem-solving, reasoning, fluency and metacognition in mathematics need to continue in collaboration with teachers.
3) Accountability systems and structures need to ensure that they do not unintentionally narrow the curriculum or the nature of mathematics students experience, and do not result in reduced resources and support for lower secondary school in order to target students involved in publicly reported measures.
4) Ensure mathematics teachers are offered the time and opportunities to develop their practice within a supportive culture.
5) Students need more time to reason, explain, discuss and justify their mathematical reasoning within lessons.

6) Ensure learning experiences enable students to understand the purpose of what they are learning, and its relevance to real-world contexts, other curriculum areas and within mathematics itself in order to maintain students' interest and motivation.

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Introduction

This report summarises the work of the Joint Mathematical Council working group examining the learning and teaching of mathematics in lower secondary schools within the UK. The group drew on a range of evidence covering each of the UK nations to identify what we know about mathematics teaching and learning in lower secondary school.

Lower secondary school is a crucial point in students' experiences of learning mathematics. For many students, their progress in mathematics slows, and fewer students have positive attitudes towards mathematics. This report begins by outlining the importance of mathematics in lower secondary schools. The rest of the report is then organised around three themes: Equity and opportunity; Pedagogies and practices; and Engagement and motivation. These themes were identified by the working group as the most pressing issues affecting mathematics teaching and learning in lower secondary schools. In addition, a thread relating to transition weaves through these themes. In this report, lower secondary school refers to students aged 11–14 years in England, Northern Ireland and Wales, corresponding to Years 7–9 in England and Wales and Years 8–10 in Northern Ireland, as well as students aged 12-15 years in Scotland, corresponding to school Years S1–S3. While this report considers teaching and learning in lower secondary school across the four UK nations, the available evidence base that directly focuses on this period of students' mathematical education is dominated by studies focusing on England.

The Importance of Mathematics in Lower Secondary School

Evidence consistently points to a dip in mathematical attainment and attitudes towards mathematics in lower secondary school across the UK (1-4). Progress in mathematics slows (5). Interest in mathematics falls. This is also a period where existing inequalities in achievement relating to students' socioeconomic background grow (6, 7). The gap between high and low achievers also widens (5). Similarly, gender and socioeconomic differences in attitudes towards mathematics become more pronounced (5), with fewer students reporting that they enjoy learning mathematics or feel confident in doing mathematics across all the UK nations (3, 8-10). Towards the end of lower secondary school, students begin to make decisions about their future studies and, in particular, their future mathematical studies, which are influenced by prior mathematics experiences (11, 12).

Prior attainment in primary and early secondary strongly predicts achievement at age 16 and age 18, yet socioeconomic factors account for between 8–13% of the variance in mathematical progress (5). In 2025, 74% of students in England met the expected standard in mathematics at the end of primary school though this drops to 61% for students facing socioeconomic disadvantage (13), and 79% of students in Scotland met the expected standard in numeracy at the end of primary school (14). As well as students facing socioeconomic disadvantage, students with special educational needs and disabilities or additional learning needs, as well as those who are looked-after children or children in need, are particularly at risk of underachievement and disengagement (15).

Teachers of mathematics in lower secondary education are, on average, less experienced and in some parts of the UK less well-qualified in mathematics than those teaching older students (16). Moreover, students aged 11–14 are disproportionately affected by the shortages of specialist mathematics teachers (5). These differences in the qualifications and experience of those teaching mathematics in lower secondary school are often more pronounced in schools with larger proportions of students receiving free school meals, and these schools also report more difficulties recruiting and retaining mathematics teachers (17).

Across all four UK nations, the mathematics curriculum for lower secondary schools prioritises the development of mathematical fluency, reasoning, and problem-solving. In Wales and Northern Ireland there is also a strong emphasis on the application of mathematics in real-world contexts, while Scotland's *Curriculum for Excellence* places particular importance on the connection between mathematics and other subjects and areas of learning. Large-scale international studies of mathematics learning (8-10, 18, 19) show consistent patterns across the UK: students in all four nations tend to perform relatively strongly in data handling and probability, but less well in geometry, space, and measurement (8-10, 18, 19). Emphasis in the curriculum also appears not to be evenly distributed across the different content areas, with a stronger emphasis on number in the early stages of lower secondary school (17).

Attainment and attitudes at this stage of students' mathematical education influence their subsequent subject and career choices, which are often shaped during the transition to upper secondary education. These findings underline the importance of focusing on mathematics teaching and learning in lower secondary school.

Transition to lower secondary schools is where the majority of students change to being taught by specialist teachers for each of their curriculum subjects, rather than having one teacher for the majority of their subjects. The transition to lower secondary school is often accompanied by a stalling of progress in mathematics and a drop in interest, confidence and engagement and an increase in anxiety in mathematics (20, 21). While primary teachers estimate that around one-fifth of students leave primary school without fluency in any area of mathematics, secondary teachers estimate that around 30% of students start secondary school without this fluency (22). One potential explanation is the revisiting of material, which students can find less interesting, at the beginning of lower secondary school (17), but is argued to be essential for securing a strong foundation to build on in later teaching (23).

Mathematics for All: Equity and Opportunity

There is a clear commitment across the four UK nations to close the gaps in mathematics achievement associated with socioeconomic background (24). Yet despite additional funding, targeted interventions, and other policy initiatives, this gap stubbornly remains (e.g., 25). There is also evidence that the gender gaps in achievement are widening (3) and the students from disadvantaged backgrounds make slower progress in secondary school (26).

Whilst gender and socioeconomic disadvantage have been widely reported on in relation to gaps in mathematics achievement (27), an intersectional lens on disadvantage includes links to differences in outcome based on ethnicity and wider social, cultural and linguistic factors (17, 28-30), acknowledging that not every student or teacher experiences differences in opportunity in the same way (29). Evidence shows gaps in outcomes for students with learning differences and disabilities or additional learning needs, as well as those who are looked-after children or children in need (15). Furthermore, students with diagnosed or undiagnosed specific learning differences can be disadvantaged by pedagogical and curriculum features such as those outlined in the section on pedagogies and practices. Outcomes for some groups of students are particularly complicated by factors such as grouping or setting practices across each of the UK nations (8-10, 28), with grouping by prior attainment being far more common in mathematics than in other curriculum areas in lower secondary school (31).

Achievement

Most of the evidence addressing the social justice dimensions related to mathematics learning and teaching focuses on gender and socioeconomic background. There are persistent gaps in mathematics performance linked to socioeconomic background in all four UK nations (1, 3, 8-10). These gaps continue despite extensive interventions (32) and widen during lower secondary school. In Scotland, the share of variation in mathematics performance explained by socioeconomic status has nearly doubled since 2018 (19). There are nation- and region-level gaps also associated with differences in mathematics achievement; regions with greater levels of socioeconomic disadvantage have lower mathematical outcomes than more affluent regions (10, 15). Of particular concern are students who face socioeconomic disadvantage over a prolonged period of time (28). Differences in academic achievement are also echoed in students' perceptions of transition to lower secondary school for those from disadvantaged backgrounds (21), as well as for students with low prior attainment in mathematics and lower self-esteem (20). These differences influence the stalling of progress for students in lower secondary school.

The picture for gender differences is more varied, but generally, boys tend to outperform girls, and this gap widens with age in each of the UK nations (8-10, 19). TIMSS focuses specifically on students in lower secondary school, and showed a widening gender gap in England particularly during lower secondary school (3). There is more limited evidence specifically focused on lower secondary school students, and the size of the gender gap in assessments taken by older students, such as national assessments, varies from year to year, often with boys performing more highly than girls (8-10). There are also strong gender differences in both confidence in mathematics and the perceived value of mathematics (3). Fewer girls than boys continue with mathematics when it becomes a subject they can choose to take (5), even where mathematics attainment at this stage is comparable. This difference widens into undergraduate and again into postgraduate studies of mathematics (17).

The evidence is more limited on the experiences of multilingual (EAL) students and those with Special Educational Needs and Disabilities or students with Additional Educational Needs (those with SEND, ASL and ALN). Immigration background has a limited impact on performance (8-10, 19), particularly for students who have been in the UK for some time. Achievement gaps between students who speak a different language at home than the one used in school are not always significant, and in mathematics, sometimes achievement for these students is higher than those who speak the same language at home as they speak in school (1). Students with SEND or ALN generally have lower attainment in mathematics than their peers (15).

The Nature of Mathematics

Students' background and characteristics not only relate to their mathematical achievements, but also impact the nature of mathematics teaching they experience in school. In England, students with lower prior attainment at the end of primary school or from a more disadvantaged socioeconomic background tend to experience a curriculum that emphasises number, with less mathematical reasoning, geometry and fewer experiences of mathematical problem-solving (3, 17, 19). Students with low prior attainment are also less likely to experience mathematics lessons that encourage discussing mistakes, sharing students' ideas, making connections and engaging with realisable or authentic contexts (17, 33). In TIMSS, which also focused on England, the performance gaps by socioeconomic background and by gender appear wider in the reasoning domain than in the procedural domains (3). Students from a more disadvantaged socioeconomic background receive less exposure to conceptual explanations, less questioning and more procedural practice, while those from a less disadvantaged background spend more time with algebraic reasoning and multi-step problem-solving (34, 35). All students benefit from opportunities to reason, explain, discuss and justify their mathematical reasoning within lessons.

Perceptions of the mathematics teaching students experience also differ depending upon student characteristics. More boys than girls report finding mathematics teaching clearer (3), and girls tend to mention opportunities to collaborate, explore and make connections in mathematics as missing from their learning experiences, and as lacking realisable applications and understanding how mathematics is used in society (11). Secondary students often experienced mathematics lessons as lacking challenge, being repetitive and disconnected from real-life applications (36). There is some evidence that teachers making their pedagogic rationale more visible supported the engagement and achievement of students from disadvantaged backgrounds (37, 38).

Historically, there has been a strong correlation between a student's socioeconomic background and the teaching group students are placed in, where students are grouped by prior attainment for mathematics. This is far more common in mathematics than in other curriculum areas (39). This practice has been shown to impact students' attainment and experiences of mathematics in different ways (24, 40), but does not consistently explain differences in mathematical achievement. Students in lower attainment groups are more likely to have less experienced and less qualified mathematics teachers (41) but also experience more disruptions due to student behaviour in their mathematics lessons (42).

Specific Learning Differences

The terms used in each of the four UK nations to describe students who have specific learning differences include SEND (Special Educational Needs and Disabilities) in England, SEN in Northern Ireland, ASN (Additional Support Needs) in Scotland and ALN (Additional Learning Needs) in Wales. In this section, we focus on how these needs can negatively influence students' learning in mathematics. The subtitle heading focusing on learning differences is intended to acknowledge that for some students, these needs can support their learning of mathematics.

The recently published guidance for and definition of Specific Learning Difference (SpLD) in mathematics (43) details the processing difficulties that influence arithmetic and mathematics learning. Persistent difficulties in mathematics can negatively influence students' learning, with wider implications for development in school, personal life and work. Differences in ways of knowing mathematics can also influence a student's resilience in mathematics classrooms and is connected to, although not necessarily a determinant of, increased likelihood of mathematics anxiety (44). Difficulties in learning mathematics can be present due to differences in language processing, visual-spatial processing and factors associated with executive function, including working memory and inhibitory control. Furthermore, differences aligned with dyscalculia are identified in SASC guidance as "severe and enduring difficulty in numerical magnitude processing, particularly symbolic magnitude processing" recognising this as "the most commonly observed characteristic differentiating people with dyscalculia from those with more general mathematical difficulties." (43). However, research evidence that isolates domain specific features of dyscalculia from environmental factors remains inconclusive.

There is evidence that SpLD in mathematics are underdiagnosed at primary school (45), implying that students in lower secondary school may have barriers to learning that are not sufficiently recognised or supported, and that funding for provision to support students with additional needs in mathematics may be missed. Consequently, teachers need professional learning opportunities that enable them to recognise and respond to SpLD and other potential barriers to building accessible mathematics classrooms.

Pedagogies and Practices

Teaching is the most important school-level factor influencing student achievement and engagement in mathematics (23, 46). The theme of pedagogies and practices lies at the heart of many of the policies and initiatives. Variability in the quality of mathematics teaching limits the impact of effective interventions (47) and is associated with widening gaps in mathematics achievement, including those relating to gender (3). Video studies of mathematics teaching in England that include lower secondary students show inconsistencies in the implementation of some pedagogical approaches, particularly those related to students' cognitive engagement and formative assessment (33, 42).

Teaching practices in lower secondary school in England emphasise teacher modelling methods and opportunities for students to practise these methods for themselves (17, 33). Students report limited opportunities to discuss their ideas or work in pairs or small groups (17, 33). These practices have been attributed to the prominence of calls for 'evidence-based', and therefore often tightly structured, pedagogies, and in England, policy preferences for explicit instruction (48). Furthermore, the OECD highlights that there is not currently a shared understanding of what engagement with research evidence means (49). Consequently, there is a need to develop a shared understanding of pedagogical practices (23, 50) that include consideration of the nature of reasoning, explaining, and justifying in mathematics.

Within the theme of pedagogies and practices, three key areas of focus emerged from the review of evidence: the influence of accountability systems, identifying and using resources, and professional development. The wealth of resources, advice and support available can be challenging and time-consuming to navigate. Across each of these areas of focus, there was also a variety of terms and variations in their meanings in the guidance, reports, and sources of professional development. The plethora of terms describing different aspects of mathematics teaching can make conversations challenging and potentially polarising, and we begin by outlining some of the key terms impacting on mathematics pedagogy and practice.

Different Terms to Describe Pedagogies and Practices

One challenge mathematics teachers can encounter is the abundance of terms that are not consistently used. This includes terms such as problem-solving (48), knowledge, and understanding (51). Mathematical knowledge, for example, is often used to refer to the content of the mathematics curriculum in the different UK nations, but it is also used to describe knowing when to use this content, how to use it and why to use it. Distinctions between types of mathematical knowledge are also made, including declarative, procedural, and conditional (35), conceptual (52) and strategic and metacognitive (53). These different types of knowledge are reflected in the 'knowledge-rich' National Curriculum for mathematics in England. In contrast, the national curricula for mathematics in Scotland, Wales and Northern Ireland focus more on competencies, areas of learning and experiences, alongside skills and proficiencies.

The differences in meanings for problem and problem-solving were recently highlighted in England with Ofsted's publication of a research review, subsequently described as a position paper (35, 48), which used a widely used definition of problem-solving from before 1985, but did not reflect the extensive research in mathematics education or cognitive science since then. Partly, the differences in meanings and definitions lie in distinctions between what a problem is: word problems, routine or non-routine problems, unfamiliar problems, and problems with no obvious solutions.

Unfamiliar problems can be used to motivate a need or purpose for new ideas or methods, or an extension of existing knowledge, or to generate more understanding of an underlying concept (54). Problem-solving that applies a known mathematical procedure in a disguised form, such as in word problems, can also be useful for building familiarity with ideas and for practising identifying mathematical structures.

The overlap between mathematical problem-solving and metacognitive strategies is also considerable, with both focusing on planning, monitoring, and evaluating. There is broad agreement in the research literature that students' success in solving mathematical problems is developed primarily through engagement with non-routine and/or unfamiliar problems, supported by explicit teaching of problem-solving and metacognitive strategies (55, 56). Through using metacognitive processes students can become more responsible for their learning, which includes approaching mathematical problems independently in ways that require planning and reflecting on solutions. However disadvantaged students may be less likely to use metacognitive processes without being explicitly taught how to (23).

The meanings for the terms mathematical knowledge and problem-solving promoted in schools and classrooms influence the nature of mathematics that students in lower secondary school experience, as well as what they perceive mathematics to be. These distinctions are evident not only in the National Curricula in each of the UK nations, but also in the discourses surrounding professional development, engagement with evidence and research, and the mathematics that is emphasised in the classroom. In Scotland, for example, there is an emphasis within the curricular guidance on experiences which connect to mathematical thinking and behaviours such as working systematically, exemplification, connecting multiple representations and generalising. This is echoed in models of mathematical thinking, such as that used by NRICH (57). In England there is more of an emphasis on content and mathematical fluency. While these conversations largely focus on fluency with number and mental arithmetic (58), particularly in primary education, there is growing evidence of the importance of spatial reasoning, which is a relative area of weakness for students across the UK nations (27).

There is a wealth of resources and guidance available to mathematics teachers, many of which are high-quality and can support effective mathematics teaching. However, this section highlights how different organisations and resources use terms like problem solving in different ways which can be confusing, can limit professional discussions and the implementation of evidence-informed pedagogies and practices.

The Role of Accountability Systems

Changes to mathematical pedagogy and practice can be both supported by and constrained by accountability systems. In this section, we consider accountability in terms of responsibilities for examination outcomes, responsibilities for teachers as professionals with a commitment to professional development, and responsibilities for schools and mathematics departments to monitor and improve their practices in relation to school systems. Arguably, the pressure of accountability systems is somewhat lighter in lower secondary schools across the four UK nations, with students taking fewer high-stakes assessments compared to the end of primary school or after the age of 14. There is consequently greater emphasis on school self-evaluation and improvement rather than the more public accountability measures used in later years. However, this lighter pressure may result in resources being directed to students taking high-stakes assessments included in accountability measures. The importance of low-stakes monitoring of students' learning (24), particularly in the transition from primary to secondary school, is fundamental to effective mathematics teaching. This was emphasised in the Curriculum and Assessment Review in England (58), which recommended a diagnostic mathematics assessment mid-way through lower secondary school to support this monitoring of learning following the transition to secondary school.

There can be tension between what mathematics teachers value and what is measured in accountability systems. Accountability systems can narrow both curriculum and pedagogy towards tested outcomes, and this tension can undermine teacher engagement (59). This is particularly salient for lower secondary mathematics, where mathematics departments may feel accountable (formally or informally) through the need to prepare for and predict outcomes in future high-stakes assessments, even when they see broader mathematical thinking, reasoning and disposition as more educationally important. Mathematics teacher shortages and issues around administrative workload can also impact teacher engagement and well-being (16, 60), with "*more than 80% of Year 9 students were taught mathematics by teachers who reported they were affected either a lot or a little by needing more time to assist individual students and having too many administrative tasks*." (p.15) in England (3).

Several reports highlight the importance of teachers engaging with evidence and research in informed and contextualised ways. The important role of leadership within education systems is highlighted as key to teachers' engagement with and production of evidence-based pedagogies (49, 61, 62). Opportunities to do this, however, can be limited in some contexts where teachers' engagement with evidence and research is directed through school- or department-level accountability systems and limited to the implementation of conclusions and recommendations (62). It is important for schools and professional development providers to not only support access to research evidence, but also to communicate this research evidence in ways that enhance teachers' and school leaders' opportunities and motivation to use both the evidence available and the recommendations made (63). Developing classroom practices that take place within a safe culture, where "*implementation strategies which maximise agency, autonomy, and connection amongst and between school communities*" (p.10) are most effective. (63).

Engaging with Evidence-Based Practices

In today's educational landscape, teachers have access to an ever-expanding range of resources from research evidence and clearinghouses that produce evidence-based guidance and summaries, to commercial tools and professional networks such as the Association for Mathematics in Education (AMiE), the National Centre for Excellence in the Teaching of Mathematics in England (NCETM), or the Scottish Schools Education Research Centre (SSERC). This section focuses on the availability of evidence-based resources, but teachers also need the time and opportunities to engage with these resources, which is considered in the next section.

In England, the majority of mathematics departments follow a curriculum developed at the school level (17), but a growing proportion of schools are adopting published or commercial schemes, and national materials funded by the Department for Education have recently been published by the Oak National Academy. Many of these curricula draw on research evidence in their design but manage the tensions involved in different ways (64). While teachers commonly rely on a combination of internal assessment data, professional experience, and colleague advice, evidence-based academic research tends to be used less frequently (65, 66).

Most teachers believe that research evidence can improve practice, but its use depends on perceived practical relevance and trustworthiness (67). In this context, knowledge brokers and clearinghouses[1], such as the EEF and OECD, often serve as trusted intermediaries, translating research findings and evidence into accessible practice-focused guidance. For example, in England and Wales, the EEF guidance reports draw on high-quality research evidence to identify core aspects of effective mathematics pedagogy (2) and is widely used by schools and teachers of mathematics.

Knowledge brokers act as mediators between academic research and classroom practice. They reframe evidence into actionable formats that align with the reality of teachers' daily needs (68). Clearinghouses serve as repositories that collect, synthesise, and curate research evidence to make it more accessible. Certain knowledge brokers and clearinghouses may be more familiar to teachers and educational institutions and become a 'go to' resource. Additionally, a growing number of schools now have a member of staff whose job is to help teachers engage with research (31).

While these resources can be valuable, it's important to recognise that both knowledge brokers and clearinghouses influence which forms of evidence are prioritised in their guidance (69). Their decisions about what counts as 'important' or 'rigorous' can also shape educational priorities (70, 71). As such, teachers must engage critically with these sources before local implementation.

Research networks can foster critical, context-specific engagement with evidence. Teacher-led enquiry, where practitioners investigate 'what works' in

[1] In this context, a knowledge broker is an organisation that helps research-informed knowledge move into practice by curating, translating, and supporting the use of evidence-based schools. A clearing house is an organisation that gathers and appraises research using transparent methods, which it uses to provide accessible syntheses (often with quality ratings) to guide teacher and school decision-making.

their own setting, can be particularly powerful (72). Although a distinction exists between engaging in research and engaging with research, teachers who undertake enquiry are often more inclined to engage with external evidence (73). These two modes of engagement are not mutually exclusive and can complement one another. Research and other professional networks offer opportunities for teachers to share and reflect on what has worked in specific contexts.

Alongside research evidence, a wide range of commercially available resources and intervention packages is available. The strength of the evidence base underpinning these varies considerably (74). Many commercial resources have a cost implication but can save on planning and resource time. Teachers must use their professional judgment to evaluate marketing claims and assess whether these materials truly suit the needs of their students and school context. Commercial resources can provide scaffolding, especially for teachers with less experience in teaching mathematics. As such, they are often less flexible and potentially limit teacher autonomy (75) as well as limiting teachers' exposure to the mathematical structure that underpins the design of many resources.

Teacher autonomy is a central feature across all four UK curricula. In an Observatory for Mathematical Education report (16), 87% of KS3 mathematics teachers in England agreed or strongly agreed that they have the autonomy to exercise professional judgment in mathematics teaching, though this does not specify the areas in which they have such agency. This sense of agency plays a crucial role in shaping decisions around resource use. Autonomy enables teachers to select and adapt evidence-based interventions to their context, integrate knowledge and material drawn from knowledge brokers or clearinghouses into their own lesson designs and choose between externally supplied packages and teacher-generated strategies based on classroom realities (76). Where there is high teacher autonomy and confidence, teachers can select and adapt different types of resources for different purposes. Conversely, when autonomy is constrained or confidence is low, teachers are more likely to adopt prescriptive solutions. There is variation in mathematics teaching practices, even when ostensibly following the same evidence-based approach, which can limit the impact of interventions and may also interact with the growing attainment gaps between different groups of students, as described in the section above considering equity and opportunity.

When teachers draw on evidence or resources, they need time to plan for this in their teaching and to consider the impact on student learning. For evidence-based resources to meaningfully improve practice, education systems need to do more than just provide materials, they must also provide time and support teacher agency. Recent research has identified the potential of AI to support the navigation and adaptation of these resources (77).

Professional Development

High-quality sustained professional development has measurable effects on both student learning and teacher practice (78). There is also evidence that stronger effects are found when professional development is subject-specific and tightly focused on improving practice (79). The importance of engagement with research being integrated into professional development is highlighted (80).

Mathematics-specific professional development is a key lever in improving mathematics teaching in lower secondary schools. The effectiveness of pedagogical approaches, including evidence-based teaching approaches in mathematics, depends on *how* changes are enacted and supported in schools (63).

Teachers need time to develop their practice, including time to collaborate. Implementing changes to existing practices or developing new practices involves an ongoing process of adaptation and enquiry (63). However, teachers often report that their workload is a major barrier to their professional development (81). In England, the majority of mathematics teachers in lower secondary school report that they have accessed subject-specific professional development (16). Recently, a survey of lower secondary mathematics teachers in England reported that teachers wanted more professional development relating to teaching problem-solving skills, as well as integrating technology into their teaching (3, 16). At present, technology is not widely used in the teaching of mathematics in lower secondary schools beyond presentation tools (17, 33). There are arguments that teachers are missing out on opportunities to transform mathematics learning through the use of technology and tools (5), and the growth of generative AI has the potential to fundamentally shift the use of technology in mathematics teaching and mathematics learning. However, the use of technology is often left to individual teachers and depends on the availability of resources, no longer featuring as a component of some curricula or in high-stakes examinations within the accountability systems in which teachers work.

Engagement and Motivation

At the end of primary school, students generally have positive attitudes towards mathematics (3, 17). Primary students report seeing mathematics as valuable and important, alongside saying they enjoy mathematics. They also generally report being confident in mathematics. However, a growing number also report feeling anxious in relation to learning mathematics (17). The majority of students in lower secondary school are also engaged (47). However, the proportion of students who report liking learning mathematics or feeling confident in mathematics at the end of lower secondary school has decreased over time (3). Positive attitudes towards and about mathematics are strongly associated with performance in mathematics. They are also important for their own sake. Engagement is both an educational outcome and a process driven by challenge, curiosity, and contextual relevance (23).

Recent reports focused on evidence-based pedagogies and practices all highlight the importance of addressing engagement and motivation, as well as achievement (23, 61). In lower secondary school there appears to be a significant change in students' engagement in mathematics (32) since leaving primary school. However, knowledge brokers such as the EEF highlight the need for more evidence on the most effective ways to foster motivation in mathematics (2).

Students' effort in learning was more strongly associated with achievement than their interest in learning (15). Other characteristics, such as resilience, coping, and persistence, are positively correlated with attainment, whereas there are negative associations with attainment among students with relatively poor physical or mental health. The impact of many of these affective factors differs depending on the gender and socioeconomic background of the students (3), reinforcing the differences in students' achievements and participation discussed in the earlier section.

There are different types of engagement (82). Behavioural engagement is the extent of the physical effort and persistence students exert during learning. Cognitive engagement is the task-focused attention, concentration, and problem-solving strategies students draw on during learning. Emotional engagement describes the enjoyment and interest students display, while Agentic engagement describes how students constructively contribute to the teaching and learning, for example, by asking a question.

The way students engage in mathematics is often indicated by their level of participation and involvement, which, in turn, is influenced by a range of cognitive, motivational, affective, social, cultural, and familial factors. There is persistent evidence that both cognitive and non-cognitive functioning positively influence attainment. Behavioural engagement is the strongest predictor of achievement (82), and the type of engagement most reported on by teachers; however, there is often less attention to, or development of, cognitive engagement in mathematics classrooms (33, 82).

Emotional engagement is the strongest predictor of motivation (82). Yet teachers in secondary schools, as well as reporting a smaller proportion of students who enjoy mathematics, also appear to place less importance on students having a sense of enjoyment and curiosity about mathematics compared to primary teachers (83).

Students are often more engaged when they have opportunities to make choices, work in pairs and small groups, share and discuss their thinking and use a range of resources, including digital technologies (47). The importance of a curriculum that students find relevant (5, 47) is also positively associated with students' engagement and motivation (23, 47). Positive relationships among and between students and teachers are also important in laying the foundations for a positive tone to learning in mathematics (47). Overall, teaching that enables students to understand the purpose of what they are learning, and its relevance to real-world contexts, other curriculum areas and within mathematics itself supports students' interest and motivation in mathematics.

Intrinsically motivated students are motivated to engage in learning activities because they find them interesting and have the autonomy to do so. Extrinsically engaged students engage because they receive approvals or avoid punishments, which can reduce interest and result in less optimal functioning and learning outcomes (15). Students who engage in mathematics because they like it have higher mathematics achievement than those who do not (3).

Another key factor that supports mathematics achievement is a strong self-concept (15). Self-concept is typically influenced by a range of factors, including parent/carer, teacher and peer perceptions of a student's abilities. A positive self-concept can also act as a precursor for motivation to study. Similarly, students' confidence and the value they see in mathematics are also positively correlated with their achievement in mathematics (3).

Conclusion

Lower secondary school is a critical inflection point in students' mathematical experiences and achievement. There are notable shifts in students' attainment, confidence, enjoyment and engagement in mathematics during this period, with the transition from primary school playing a significant role in this shift. At the same time, long-standing inequities associated with students' socioeconomic background, gender, and SEND are widening further, shaping both students' experiences of learning mathematics and their mathematical opportunities. These patterns are concerning not only because of the impact they are having on students in lower secondary education but also for their longer-term engagement with mathematics. Mathematics teachers play an essential role in shaping these outcomes and opportunities. Sustained mathematics-specific professional development, opportunities for teacher collaboration alongside system-level support are all critical to enabling teachers to support students during this period of their mathematical education.

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