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# Rapid Evidence Assessment on 'What Works' for Numeracy Teaching

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## Welsh Government

Views expressed in this report are those of the researcher and not necessarily those of the Welsh Government

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# Key Findings – Summary

To support the Welsh Government (WG) National Numeracy Programme announced in September 2012, a Rapid Evidence Assessment (REA) was conducted in-house by Knowledge and Analytical Services to examine the available evidence on 'what works' in the teaching of numeracy.

Assessing the most relevant factors which have been demonstrated to 'work' to improve numeracy is a difficult task, due to the contradictory findings within the literature. However this Rapid Evidence Assessment has identified five overarching themes:

1. Curriculum factors.
2. Teaching practice.
3. Teachers professional development.
4. Interventions.
5. Use of ICT and technology.

Within these five themes, a set of key factors emerge which seem to ensure effective numeracy teaching.

1. Curriculum factors

- Integration of numeracy across the whole curriculum and not just being solely considered as 'taught mathematics'.
- A curriculum that is well-attuned to the country-specific skills need and that teaches basic concepts and principles that can be applied in later life outside of a purely mathematical context.
- A curriculum which is developed to suit the specific cultural context.
- A curriculum which is clearly aligned with its assessment regime.

2. Teaching practice
    - Collaborative teaching practices that encourage pupils to work in mixed ability groups with aspects of peer learning.
    - Scaffolding teaching practice.

3. Teachers' professional development
    - Improving the levels of both subject-specific knowledge and pedagogical content knowledge for teachers of maths, this can be considered at both the initial teacher training and also in combination with recognition of the importance of continuing professional development.

4. Interventions
    - Well designed, individually tailored intervention programmes for pupils that have mathematical difficulties, key to this is an appropriate system of early identification of difficulties.
    - Early intervention for those children who experience mathematical or numerical difficulties.
    - A dedicated maths specialist at school or local authority level.

5. ICT and technology
    - Tentative evidence that ICT and technology could have a part to play in effective numeracy teaching.

This REA considers each of these themes in turn while highlighting that given the number of factors identified, there is no clear consensus within the evidence of the most important factor rather that they are inter-related and cannot be considered in isolation.

# 1. Introduction

1.1 The question of what works in teaching numeracy is a highly important one for policy-makers and education academics, and has provoked a great deal of research. This research has led to numerous different and often conflicting suggestions and conclusions about the most effective way to teach numeracy in schools.

1.2 In December 2011, the Knowledge and Analytical Services department of the Welsh Government was tasked with undertaking a review of the available evidence base concerned with what works for the effective teaching of numeracy for children aged 5 -14. The aim of the review was to inform the development of the National Numeracy Programme.

1.3 The review has been conducted as a Rapid Evidence Assessment (REA), with the following aim:

- To undertake a Rapid Evidence Assessment (REA) on published literature on the subject of interventions, policies and programmes designed to improve and maintain increased levels of numeracy attainment in children aged 5-14.

1.4 The REA considered five areas:

i) Gathering together definitions of numeracy.

ii) Gathering statistical evidence of Wales' performance in numeracy.

iii) Gathering evidence of what other countries/regions/provinces/local authority areas have done or

are doing in an attempt to improve numeracy levels amongst children aged 5-14.

iv) Grading of interventions based on the results of their evaluations.[1]

v) Depending on the nature and quality of the literature obtained, provide a breakdown of the evaluations of the interventions to provide information on what works to improve numeracy attainment by age/gender/ethnicity/socio-economic group.[2]

1.5 The REA has been undertaken alongside the development of the National Numeracy Programme in order to inform it and is published alongside the Programme in order to make explicit the evidence which has informed it. It is not intended to provide a blueprint for planning or decision-making regarding numeracy in Wales. However, it is hoped that the evidence it provides will contribute to the evidence base to inform numeracy teaching, policy-making and practice. In addition, it will also highlight gaps in the evidence which may be filled through further research.

## 2. Methodology

2.1 The Government Social Research toolkit protocol[3] for an REA was used as guidance to ensure that high quality control procedures were followed and a rigorous and robust assessment of the evidence was conducted. The Welsh Government Library Service undertook the literature searches and sourced the literature.

[1] While it was not possible to 'grade' the interventions in their own right, a grading of the evidence was undertaken and is found in Appendix C.
[2] This was a lower priority objective and given the nature of the evidence obtained, this was not undertaken.
[3] http://www.civilservice.gov.uk/networks/gsr/resources-and-guidance/rapid-evidence-assessment

2.2 Priority areas were identified to inform the search terms and maximise the results obtained by the literature search. The agreed search terms and the list of databases that were searched can be found in Appendix A. It was agreed for reasons of practicality to limit the literature search to those in English only and also a decision was made to only search for literature published after the year 2000. This was to not only provide a limit to the volume of data to be generated, but also it was decided that this date limit would ensure that the literature identified could still be regarded as 'contemporary'. The additional inclusion and exclusion criteria used to assess the suitability of the literature for study, can also be seen in Appendix B. The Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI – Centre) guidance for inclusion and exclusion criteria suggests, *"explicit inclusion and exclusion criteria are developed for specifying which studies will be included in the review. For example, criteria in terms of study topic, population and setting and, of course, study design. Time and effort spent on this stage is likely to save time and trouble later*." (EPPI – Centre 2010 p.4). The criteria listed in Appendix B were agreed after discussion with policy colleagues to ensure that the focus of the review was appropriate and suitable to answer the research question.

2.3 The REA was conducted between January and May 2012. The initial search yielded 71 results including books, links to research reports and output website pages, journal articles, conference papers, evaluation reports and governmental research reports. Having obtained as many of the articles that it was possible to access, an initial title and abstract screening process was carried out to sift out any results that fell outside the scope of the project, leaving 38 articles to go through a secondary more in-depth abstract screening process.

2.4 Following the second abstract screening process, 25 articles remained; each was assessed using a data audit form (see Appendix D) that took

account of factors such as the methodology employed, the key findings and the type of data used. This process resulted in the identification of 15 articles suitable for inclusion in the report.[4] These articles report on studies and evidence reviews conducted across a number of countries and on a number of differing areas of interest. In several instances these articles are systematic reviews.

2.5 The REA was also submitted for peer review by two academic experts in the subject of numeracy and numeracy teaching. Their responses to this peer review were used to inform this final report and the Welsh Government would like to thank Professor Lianghuo Fan of the University of Southampton and Professor Peter Bryant of the University of Oxford, for their invaluable comments at the peer review stage.

## 3. Limitations

3.1 As with any review it should be borne in mind that while within this REA there are likely to be gaps in the evidence and that the evidence to plug those gaps may actually exist, the REA operates within its own boundaries and limitations, access to suitable material is perhaps the key limitation of this REA.

3.2 It is worth stressing that the findings within the literature are mixed, with contradictions and disagreement on what is the most effective approach among the many different aspects that are considered. Some reports advocate one approach while others suggest that an alternative holds the most significant effect, others may suggest that a combination of approaches will offer a solution. It is therefore difficult to make an outright assessment of the most effective practices as direct comparison is problematic.

[4] The full list of articles selected can be found in the References but a list of the key texts relevant for each theme is detailed at the end of each section.

3.3 At the outset of the work, it became clear that the literature on the subject was wide-ranging with a degree of variability concerning the size, scope, focus and claims of effect and effect magnitude within the available evidence. This is a point stressed by Slavin *et al* (2008) who make the valid point in their evidence synthesis:

> *"One of the most difficult issues in the review of "what works" research is in summarizing outcomes of many studies, balancing factors such as methodological quality, effect sizes,*[5] *sample sizes and other factors." (*Slavin *et al* 2008 p43)

3.4 On a related note for this work, and perhaps serving to act as a note of caution, the authors of a research report examining the factors underpinning those educational systems that are recognised as 'high performing' in international comparison assessments state that:

> *"There is an underlying assumption to many international comparative studies that the answer to successful mathematics teaching is 'out there'; that somewhere, someone has an education system that 'works'. If not in one country, then maybe the answer can be found by looking across several – put together school organisation from one place, with approaches to training teachers from another and pedagogic practices from a third, and a composite solution will emerge.* ***Our review of the research suggests that finding the 'roots' of success is an unattainable fantasy…..****There is much we*

[5] 'Effect size' is simply a way of quantifying the size of the difference between two groups. For a simple explanation of this, see http://www.leeds.ac.uk/educol/documents/00002182.htm

> *can learn from research into high-attaining countries, but it is indirect. It can help us hold a mirror up to our own practice, to raise questions to reflect back on ourselves."* (Askew *et al* 2010 p14 – emphasis added).

3.5 This notion is also alluded to in a review of numeracy undertaken by the Department of Education in the State of Victoria, Australia, who consider the international evidence including analysis of PISA[6] and find that:

> *"One of the more intriguing outcomes of recent international comparative research is the diversity of classroom practice that characterises even those countries with similar levels of student achievement. Yet the pictures that are emerging … of mathematics classes in these countries are very different … Such findings … suggest that 'good practice' is a culturally determined entity"* (Clarke 2006 – cited in State of Victoria 2009 p16).

3.6 With these limitations in mind, the evidence discussed in the paper is presented as the most relevant and suitable data that meets the quality criteria and was available and accessible for the REA.

[6] OECD Programme for International Student Assessment

# 4. Background Context

4.1 PISA mathematics scores show that Wales is not performing as well as the other UK countries or at the OECD average (see table 1).

**Table 1: PISA Mathematics scores, UK and OECD average (2006 and 2009)**

| | **Wales** | England | Scotland | Northern Ireland | OECD average |
|---|---|---|---|---|---|
| 2006 | **484** | 498 | 506 | 494 | 498 |
| 2009 | **472** | 492 | 499 | 492 | 496 |

*Source: PISA and NFER*

4.2 A 38 point gap from the OECD average is taken to be the equivalent of one school year in education. The difference of 24 points between Wales' score and the OECD average, would indicate that Welsh children are the equivalent of over half an academic year behind that average. Sixty-five countries took part in PISA 2009. For mathematics, 35 countries performed better than Wales.

4.3 Beyond the PISA results, there is an absence of numeracy measures. In this case, maths results are used as a proxy to give an indication of existing numeracy standards. In the 2010/11 GCSE results for Wales, 60 per cent of entrants in GCSE mathematics achieved grade A*-C.

4.4 There is a gender split on maths attainment, in 2010/11 more boys gained GCSE A*-C in mathematics than girls.

# 5. Defining Numeracy

5.1 Numeracy is the main focus of this REA but the emergent trend in the literature was that 'numeracy' was associated by default with the teaching of mathematics, although there is not even universal

agreement about the use of 'numeracy' as a term with some preferring 'Quantitative Literacy'.[7] For the purposes of this REA however, we use 'numeracy'. This assumption that maths, mathematics and numeracy can be used interchangeably conflicts with the wider, and perhaps more accepted, definition of numeracy which regards numeracy as being much more than proficiency in just mathematics, as Estyn, the body charged with inspecting and assessing quality and standards in education and training providers in Wales, notes in its own definition:

> *"Numeracy is not the same as mathematics. Numeracy is a proficiency with number that is acquired through being taught mathematics well. Although learners usually learn their numeracy skills during mathematics lessons, to be fully numerate they must be able to apply these skills in other subject areas and real-life contexts."*
> Estyn (2011) p.6

5.2 There is not one definition of numeracy; there are numerous, making it difficult to ensure that the same concepts are being examined across the included literature. Recently, the Welsh Government commissioned a report to examine what works in terms of numeracy assessment. As part of this report, the authors provided a numeracy definition to be used by the Welsh Government in future. This definition of numeracy is:

> *"The competence and confidence in using numbers to represent quantities and also the skills in reasoning that children can use in order to understand relations between quantities, to model problem situations, to make quantitative predictions, and also to assess the probabilities*

[7] At the peer review stage, a reviewer suggested 'mathematical proficiency' should also be included. It was not possible to retrospectively consider this definition, but it should be noted for any researchers considering investigation of this topic in future.

> *of different possible events"* Bryant and Nunes (2012) p.64

As a result of this work, the Welsh Government has adopted the following definition of numeracy to inform the National Numeracy Programme:

> *"Identifying and applying numerical reasoning skills in order to solve a problem and carrying out the numerical procedures which enable people to work out and show their solutions".*

5.3 However, having highlighted the issues around assuming that the terms mathematics and numeracy can be used interchangeably, this REA does include evidence on mathematics teaching given the volume of evidence that also uses mathematics teaching as a proxy for numeracy.

# 6. Introduction to Key Findings

6.1 Five overarching themes were identified in the literature:

1. Teaching Practice.
2. Teachers' Professional Development.
3. Curriculum Factors.
4. Interventions.
5. Use of ICT and technology.

6.2 This section briefly introduces the key findings that were identified before the following sections; 7-11 consider each in more detail. These five themes cannot be considered as being discrete and independent as they interact and influence each other to a greater or lesser degree. The research that has been included and studied may have a tendency to deal with one of the broad themes, but in practice and perhaps unsurprisingly given the topic, they do by necessity have to consider elements of the other themes.

6.3 Despite this however, the REA does aim to provide an overview of the research available on these broad themes to enable a considered view to be drawn on what contributes to the most effective factors in teaching numeracy.

6.4 This REA considers the broad themes and provides a summary of the related evidence for each. It must be stressed however that with the multiple foci of the research reports in the literature, the broad themes need to be recognised as such. There are many different investigations of the different elements of teaching practice for instance and there is no 'one size fits all' definition of teaching practice to suit all of the evidence here. Similarly, with the other themes there may be some degree of overlap where for example an element of teaching practice broaches some of the same ground as an intervention.

# 7. Theme 1: Teaching Practice

7.1 Of all of the themes identified by this REA, perhaps the most widely studied within the literature is that of teaching practice and teaching methods. This theme garnered many more articles for inclusion than the other themes (although as already highlighted it is not usually considered in isolation).

7.2 A recurring theme within teaching practice is related to the way that maths classes are delivered to pupils. Slavin *et al* (2008 and 2009) have undertaken an extensive evidence synthesis review seeking to identify the most effective programs in teaching mathematics at elementary[8] (2008) and middle and high school settings[9] (2009) (mainly based on US literature).

7.3 Their review used an evidence synthesis approach that had the following requirements for a study to be included; use of a randomised or matched control group, study duration of 12 weeks, and achievement measures not inherent to the experimental treatment. The review applies a technique called "best-evidence synthesis" which seeks to apply consistent, well-justified standards to identify unbiased, meaningful quantitative information from experimental studies, and then discusses each qualifying study, computing effect sizes but also describing the context, design, and findings of each study. Best-evidence synthesis closely resembles meta-analysis. From their review of literature across both age ranges (elementary, middle and high schools) they find that programmes affecting daily teaching practices have more effects on achievement than factors dealing with technology or textbooks (which they see as curriculum factors) alone.

[8] Ages vary by state but can include ages 5-12.
[9] Ages vary by state but can include ages 11-18.

7.4 Slavin *et al* (2009) found strong positive outcomes for student achievement associated with the introduction of co-operative and collaborative methods of learning of various kinds including small group and pair work. In the case of the elementary school-aged children the review found that there was a positive effect for methods that encouraged co-operative learning methods in which students work in pairs or small teams and are rewarded based on the learning of all team members. Their review provides more detail on the different programmes that were included in their review and they find that the greatest effect sizes[10] are found in those programmes that maximise student engagement and motivation and give students opportunities and incentives to help each other learn. This finding was supported by the findings of an evaluation by Sebba *et al* (2011) of a teaching method called 'Complex Instruction'[11] (CI).

7.5 Their study involved comparison of a number of data sources in six schools that used the CI and four comparator schools that did not. Lesson observations, interviews, pupil attitude questionnaires and test results were analysed in order to explore the learning opportunities that were provided by the CI approach, the depth of mathematical understanding, students' enjoyment in, and attitudes to mathematics, challenges faced by teachers and the support that teachers need. The evaluation found that this CI approach, introduced in a small number of schools in England, which encourages collaborative problem-solving in mixed ability groups, had no significant effect on the attainment outcomes of pupils using the technique and those in comparator schools not using the method.

[10] 'Effect size' is simply a way of quantifying the size of the difference between two groups. For a simple explanation of this see http://www.leeds.ac.uk/educol/documents/00002182.htm

[11] Complex Instruction is a general pedagogical approach that addresses the problems of under-achievement and unequal participation in mathematics by the teaching of students in mixed ability groups, where the focus of teaching and learning is on group work-based, mathematical problem-solving that also involves collaborative problem-solving. This approach has been used and evaluated in the US since the 1980s. The authors suggest that this approach has been shown to increase students' engagement and achievement in mathematics.

7.6 It should be noted however that both of the papers discussed in the previous paragraph, report on studies that utilised different methods and while both do indeed consider co-operative learning, each has a slightly different focus. The most effective approach in the Slavin *et al.* study is to use small group study to primarily improve children's meta-cognition (their awareness of their own cognitive strategies). This is done by explicit discussion among the children of how each of them tried to solve the problem. The 'Complex Instruction' approach in the Sebba *et al.* study is an approach that asks the children to undertake a more collaborative approach to learning and help each other. Hence while both do consider 'group working' there are differences in the way that this 'group working' is manifest and it may be that the reported disparity in results is attributable to this difference.

7.7 A further factor to consider when discussing the issue of the effectiveness of group-work or collaborative work in the classroom is raised by Sebba *et al.* who suggest that an evaluation of this approach should also consider the 'groupworthiness' of a task, in that some tasks are much more suited to work in groups than others and this may affect any outcomes identified as a result of this approach.

7.8 An approach was introduced closer to home as the National Numeracy Strategy (NNS) in England advocated the implementation of 'Daily Mathematics Lessons' (DML) which were referred to as 'numeracy hour'. This approach could include whole class, group and individual teaching and it was aimed at encouraging whole class interactive teaching and incorporated some elements of pupil peer-to-peer interaction. In effect the DML is a lesson planning format guideline for teachers to follow. There have been a number of studies assessing the impact and effectiveness of the approach with contrasting findings being documented.

7.9 A systematic review of the evidence of the impact of the DML led by Kyriacou and Goulding (2004) found that evaluation of the approach is

highly problematic, as all but one of the studies that they reviewed include explicit evidence of certain classroom practices which differ from those recommended in the NNS, so any conclusions on impact have to take into account what is commonly happening in classrooms rather than what is intended in the policy.[12] They find that despite the intentions of the policy to encourage the interactive, high quality discussion elements in the classroom, there was some evidence that the DML had in fact led to increased time pressure to cover the full curriculum that had led to reversion to more traditional whole class teaching but at an increased pace that could lead to problems for lower attaining pupils. This is also a factor considered by an evaluation conducted by Beverton *et al* (2005). They found that the NNS had been implemented flexibly across different schools and report similar findings with regard to the pace of the DML leading to problems where previous learning could not be consolidated.

7.10 Beverton *et al* (2005) undertook an in-depth qualitative study in a sample of nine schools in the North East of England, (three schools with reasonably consistent level 4 results in English and mathematics in each of the last three years, three with consistently better results in English and three with consistently better results in mathematics). They found that while the key features of the DML were received broadly positively by teachers and were widely implemented, the nature of the implementation was not uniform and different methods and approaches were observed. Teachers reported that they viewed the DML as contributing to enhancing pupil confidence and competence in early mathematics. These findings however, rely on the perceptions of teachers rather than any empirical data on attainment levels and in fact analysis of test results pre- and post-DML show no noticeable improvement in levels of attainment. Again Beverton *et al* (2005) also

[12] This is related to the notion of 'programme fidelity' - staying true to the original program design is referred to as programme fidelity. True fidelity may not be easily achieved in practice as practitioners often change or adapt evidence based programmes as they implement them, whether intentionally or not. – See http://whatworks.uwex.edu/attachment/whatworks_04.pdf

report similar findings – citing a report by Brown *et al* (2003) who reasoned that any improvement in attainment was unlikely to be correlated to the implementation of the DML, but rather to an emphasis on the outcomes of national tests. A finding supported by Brown *et al* (2001) who argue that on the weight of evidence they studied, a change in pedagogy is unlikely to be the main cause of any rise in attainment but that the curriculum taught is more likely to be the most important factor.[13]

7.11 To conclude this section, it is worth drawing on the findings of the State of Victoria (2009) report which presents an overview of the international literature across a range of factors dealing with numeracy teaching. This report proves a useful source, and makes the observation that having synthesised the findings of a literature review undertaken to identify and present findings from local and international research relevant to teaching, learning and using mathematics in the 21st Century literature, they suggest that the most effective teaching practices are those that:

- have clear focus on concepts and thinking;
- have an emphasis on valuing children's strategies;
- encourage children to share their strategies and solutions by working collaboratively in mixed ability groupings with opportunities for students to support one another and to share explanations; and
- encourage children to see the mathematics they are doing as important and relevant and themselves as capable of thinking and working mathematically.

7.12 Another interesting aspect to emerge from the report by the State of Victoria, is the discussion on the contrast between 'constructivist' and 'instructivist' methods and approaches to teaching. A constructivist method holds that existing knowledge is used to build new knowledge and teachers should never directly impart knowledge to students but

[13] It should be noted however that this paper is a conference paper and is not a published peer reviewed journal article.

allow them to construct the new knowledge themselves. Instructivist approaches take an alternative view that knowledge is transferred from the teacher to the student by direct instruction. The report provides a useful comparison of these approaches:

**Table 2 – Instructivist and Constructivist Teaching Approaches**

| | Instructivist | Constructivist |
|---|---|---|
| Also Called | Direct instruction.<br>Teacher-centred learning.<br>Teacher-directed learning. | Student-centred learning.<br>Self-directed learning.<br>Discovery learning. |
| Approach | Based on a transmission model:<br>teacher = expert imparts knowledge to student = novice | Based on model of construction of knowledge by student/learner with teacher as facilitator. |
| Characterised By | Reliance on textbooks.<br>Demonstration of correct method followed by student practice. | Active construction of meaning through activities, discussion with other students.<br>Use of a variety of manipulatives[14] |

*Source – State of Victoria (2009)*

7.13 Perhaps linking back to Sebba's notion of 'groupworthiness' of a task, depending on the appropriateness of a task to a certain approach, the State of Victoria report suggest that their review of the evidence shows that a teaching approach that combines complementary elements of both constructivist and instructivist approaches where appropriate, can work effectively.

[14] A mathematical manipulative is an object which is designed so that a learner can perceive some mathematical concept by manipulating it,for example blocks, interlocking cubes and tiles to denote values.

7.14 This report places an emphasis on the notion of 'scaffolding' practices within primary school teaching, where a teacher is encouraged to support the student until the student is ready to 'stand' on their own. They note that this approach features across a range of literature sources and is an element worthy of further study and consideration.

7.15 This approach is underpinned by the importance placed on teachers' subject knowledge and pedagogical knowledge and ability to combine the two to create an effective teaching method. These elements and teaching practice are clearly inter-related and will be considered under the theme of Teachers' Professional Development.

**Box 1 – Key Texts for Teaching Practice**

Key texts for teaching practice theme (Full details of the Key texts and hyperlinks where available can be found in the References section at the end of the report):

Beverton *et al* (2005) *Teaching Approaches to Promote Consistent Level 4 Performance in Key Stage 2 English and Mathematics*

Brown *et al* (2001) *Magic Bullets or Chimeras? Searching for Factors Characterising Effective Teachers and Effective Teaching in Numeracy Research*

Kyriacou and Goulding (2004) *A systematic review of the impact of the Daily Mathematics Lesson in enhancing pupil confidence and competence in early mathematics*

Sebba *et al* (2011) *Raising Expectations and Achievement Levels for All Mathematics Students (REALMS) - Final Report to the Esmee Fairbairn Foundation*

Slavin *et al* (2008) *Effective programs in elementary mathematics: A best-evidence synthesis.*

Slavin *et al* (2009) *Effective programs in middle and high school mathematics: A best-evidence synthesis*

State of Victoria Department of Education and Early Childhood Development. (2009) *Numeracy in practice: teaching, learning and using mathematics*

# 8. Theme 2: Teachers' Professional Development

8.1 This theme encompasses not only issues surrounding the level of subject-specific knowledge and understanding, but also:

- pedagogical knowledge;
- initial teacher training; and
- elements of continuous professional development.

8.2 Compared to the other identified themes, there appears to be more of a consensus regarding the important role that these elements hold in contributing to effective teaching of numeracy. The evidence points to the need for in-depth knowledge and understanding of both **subject knowledge** and **subject pedagogic knowledge,** and an ability to combine and understand these concepts effectively in order for teachers to deliver effective teaching.

8.3 The Williams Review of maths teaching in early years and primary settings in the UK, was produced for the then Department for Children, Schools and Families in 2008. This review is, in effect, a literature review examining the evidence published on the subject of early years and primary settings although no search criteria and terms are provided in the report. The report argues that while teachers in this setting are not likely to be maths-specific subject teachers, there needs to be a recognition that a high level of maths-specific subject knowledge and an understanding of how to relate this knowledge in a way that enables pupils to understand complex mathematical concepts, is vital even at this level. This is echoed by a report by Rakes *et al* (2010) which, although it has a narrow focus on the teaching of algebra specifically, found that an ability to teach and develop the pupils' 'conceptual understanding' of the subject, leads to improved results rather than a focus on 'procedural understanding'. Rakes *et al.* undertook a thorough systematic review of the literature dealing with the teaching and learning of algebraic concepts. They apply a number of selection criteria to their

search and as a result of this, their study considers 82 relevant studies with 109 independent effect sizes representing a sample of 22,424 students. Their report expands on this by citing a report saying that there is a growing consensus that: “whatever students learn, they should learn with understanding” (Hiebert *et al*., cited in Rakes *et al.*, 2010 p.377).

8.4 The current minimum requirement for teachers’ acceptance at the Initial Teacher Training stage in order to teach maths, is that they have achieved a C grade at GCSE level and the Williams Review (2008) indicates that their work did consider whether this requirement should be raised to at least level 3 qualification at either AS or A-level in mathematics, or to at least a grade B at GCSE to bring the UK up to par with other countries who have set high qualification standards for entry into the teaching profession. The Williams Review however reasons that this could be impractical as it would potentially lead to a decline in numbers of trainee teachers. The review argues that while subject knowledge is vitally important, it is not sufficient in isolation as this necessarily needs to be combined with in-depth pedagogical knowledge to provide the full level of effective teaching to pupils even at KS2. Askew and Brown (2003) recommend that a deeper understanding of the maths curriculum being taught and the ability to impart principles and concepts inherent in this, are more important for effective teaching than higher level qualifications alone.

8.5 This finding is similar to those found by the State of Victoria report, this says that *how* teachers hold knowledge may be more important than *how much* knowledge they know. They explain this as “the mathematical knowledge required for teaching in the primary and middle school years. This is not the same as a knowledge of advanced mathematics” (ibid p.27). They further say that subject (content) knowledge and pedagogical knowledge are important but that a key variable is:

> *“Pedagogical content knowledge – knowledge of the ways of representing and formulating the subject that*

*makes it comprehensible to others, which includes knowledge of what makes the learning of specific topics easy or difficult, the conceptions and preconceptions that students of different ages and backgrounds bring with them. For mathematics teaching and its relation to numeracy achievement, teachers' Mathematical Pedagogical Content Knowledge is cited as a key variable in many research studies."*(Shulman 1987 in State of Victoria 2009 p.26).

8.6 This work led the authors of the State of Victoria report to produce a categorisation of the different elements required for effective teaching of early years numeracy:

**Table 3 – Characteristics of Effective Early Numeracy Teachers**

| | Effective early numeracy teachers will... |
|---|---|
| Mathematical Focus | Focus on important mathematical ideas |
| | Make the mathematical focus clear to the children |
| | |
| Feature of tasks | Structure purposeful tasks that enable different possibilities, strategies and products to emerge |
| | Choose tasks that engage children and maintain involvement |
| | |
| Materials, tools and representations | Use a range of materials, representations and contexts for the same concept |
| Adaptations/connections/links | Use teachable moments as they occur |
| | Make connections to mathematical ideas from previous lessons or experiences |
| | |
| Organisational style(s), teaching approaches | Engage and focus children's mathematical thinking through an introductory, whole group activity |
| | Choose from a variety of individual and group structures and teacher roles within the major part of the lesson |
| | |
| Learning community and classroom interaction | Use a range of question types to probe and challenge children's thinking and reasoning |
| | Hold back from telling children everything |
| | Encourage children to explain their mathematical thinking/ideas |
| | Encourage children to listen and evaluate others' mathematical thinking/ideas, and help with methods and understanding |

| | |
|---|---|
| | Listen attentively to individual children |
| | Build on children's mathematical ideas and strategies |
| | |
| Expectations | Have high but realistic mathematical expectations of all children |
| | Promote and value effort, persistence and concentration |
| | |
| Reflection | Draw out key mathematical ideas during and/or towards the end of the lesson |
| | After the lesson, reflect on children's responses and learning, together with activities and lesson content |
| | |
| Personal attributes of the teacher | Believe that mathematics learning can and should be enjoyable |
| | Are confident in their own knowledge of mathematics at the level they are teaching |
| | Show pride and pleasure in individuals' success |
| | |

*Source: Clarke et al 2001 in State of Victoria (2009)*

8.7 Within the literature in general, there is some recognition that while at primary level it may not be possible for all teachers to have a maths specialism, there is a call for the introduction of a 'Maths Specialist'[15] at each school with the in-depth subject-pecific and subject pedagogy knowledge and understanding required to perform a coaching and mentoring function for other teachers. This is an option put forward by The Williams Review (2008) and also by Beverton *et al* (2005) who see

[15] The Williams Review see this as: The Mathematics Specialist would be drawn from within the existing teaching force. This teacher will in effect 'champion' mathematics in the school and act as mentor and coach, as well as being an outstanding classroom teacher. There should be at least one Mathematics Specialist in each primary school, in post within 10 years, with deep mathematical subject and pedagogical knowledge, making appropriate arrangements for small and rural schools.

this role being performed to a point by the subject co-ordinators at each school.

8.8 In addition to the role of the mathematics specialist at each school the Williams Review (2008) recommends that local authority 'Mathematics Consultants' should act as an important link to providing continuous professional development (CPD) function for the specialists in each school, and the appropriate training provision to be funded by local authorities. The Williams Review argues that to begin the process of effective teaching of numeracy and initiate a rise in levels of attainment, the initial focus of teacher CPD in maths should be focused on the Mathematics Specialist including progression to a Masters level qualification in order to raise the level of knowledge and expertise in this role. Beverton *et al* (2005) also acknowledge the important role that local authorities should play in the co-ordination and funding of teachers' CPD.

8.9 While teacher CPD is an important aspect of the process, it should also be borne in mind that there are a variety of different attitudes towards the status that teaching has in society and the importance of the 'profession' across countries. Mourshed *et al* (2010), in a report for McKinsey on how improving school systems maintain their improvement, detail a number of countries such as Poland, Lithuania, Singapore, Finland and Hong Kong among others, have placed a high profile on improving the professional image and status of teachers and seeking to elevate the profession to a similar status as medicine or law. This could include looking to recruit a percentage of the top graduates into teaching as a career. This report by Mourshed *et al* analyses PISA results across the world and then classifies countries into a number of groups depending on their results and the progress that has been identified within these educational systems. As well as this analysis of quantitative data, they undertook interviews with a number of stakeholders within the educational systems of their sample to elicit views on the interventions and approaches that are being utilised.

8.10 A final point to be made on this theme leads into the next theme on curriculum factors as Beverton *et al* (ibid) discuss curriculum factors and some of the difficulties encountered with the content of the curriculum by the pupils, but also notes that some of the teachers encounter their own problems with understanding aspects of the curriculum. They cite subject co-ordinators who note their colleagues' difficulties in grasping aspects of long multiplication and division, fractions, shape and space, and problem solving.

**Box 2 – Key Texts for Teachers Professional Development**

Askew & Brown (2003) *How do we Teach Children to be Numerate? A professional user review of UK Research undertaken for the British Education Research Association*

Beverton *et al* (2005) *Teaching Approaches to Promote Consistent Level 4 Performance in Key Stage 2 English and Mathematics*

Mourshed *et al* (2010) *How the world's most improved school systems keep getting better*

Rakes *et al* (2010) *Methods of Instructional Improvement in Algebra: A Systematic Review and Meta Analysis*

State of Victoria Department of Education and Early Childhood Development. (2009) *Numeracy in practice: teaching, learning and using mathematics*

Williams, P. (2008) *Independent Review of Mathematics Teaching in Early Years Settings and Primary Schools,*

# 9. Theme 3: Curriculum Factors

9.1 This theme reflects the tendency of the literature to consider 'curriculum factors' in a general and broad sense rather than providing in-depth analysis of the content of the curricula. Although as will be seen in this section, there is a belief that directly transferring a curriculum or even elements of a curriculum that works in one country does not necessarily guarantee that this will translate to success in another setting.

9.2 As has already been highlighted, Slavin *et al* (2008) claimed that more effective teaching of numeracy could be ascribed to changes in teaching practices rather than factors associated with curriculum. While other studies as already discussed have also claimed that teaching practices have the leading role to play in determining effective teaching of numeracy there are counter claims that it is what is taught in the curriculum that can have a more important impact.

9.3 The Williams Review (2008) came to the conclusion that significant overhaul of the national curriculum in England at Key Stage 1 and 2 was unnecessary, this finding was however made before a subsequent review of the curriculum had reported its findings (which has not been included in this REA).

9.4 Kyriacou and Goulding (2004) make an interesting case for the interdependent nature of the curriculum and attainment, as their analysis of the literature suggests any improvement in pupil competence in maths may be attributable more to the closely related match between what is being taught and what is subsequently being tested. This assertion seems to suggest that 'teaching to the test' is inhibiting the use and application of mathematical skills in pupils and may be an underlying

reason for the relative performance in the international assessments which test different mathematical competences.

9.5 A further claim as to the important role that curriculum can play is taken by Brown *et al* (2001) who reach the conclusion that on the basis of their analysis of assessment results, any increase cannot be aligned with any claim of significant effect due to teaching practice. They conclude that the most salient factor to account for the improvement in achievement, is the curriculum taught. They also state that a number of the international studies they analysed reached the same conclusion.

9.6 If we consider the international context for a moment, the McKinsey report details different curriculum approaches that have been undertaken. This finds that in Poland, a country progressing on a 'fair to good' improvement trajectory, teachers were free to choose the curriculum they followed in classrooms from a pre-approved list of over 100 private providers. The report also details that in Hong Kong this multiplicity of curricula is even more pronounced, as the teaching approach here is very much 'teacher-led' with a freer rein to choose what is taught in classrooms than other systems. However Askew *et al.* (2010) in a report for The Nuffield Foundation, provide analysis of the system in Hong Kong which reports that despite teaching being teacher-led the same curriculum is taught up to the age of 15, so there is a disparity here – perhaps reflecting the fact that different descriptors of 'curriculum' and 'teaching' can lead to confusion when making comparisons across reports. This report is a comprehensive literature review that also considers data from the PISA and TIMMS[16] assessments and also illustrates the example of Japan, which offers a much more centralised learning system – promoting equality and homogeneity within the system, an approach that has seen Japan consistently ranked in the top 10 in international comparisons.

[16] Trends in International Mathematics and Science Study.

9.7 In their analysis of the differences noticed between countries in the international attainment measures (TIMMS and PISA), Askew *et al.* (2010) state that in their opinion, teaching is a minor factor when compared to the need for a close match between the curriculum and the testing regime in explaining the difference in results across different teaching systems. This is a factor that is also considered by Beverton *et al* (2005) who suggest that teachers and pupils recognise that at the key assessment points such as in Year 6[17], there is a tendency to teach in a manner that aims towards achieving assessment targets and that this is accepted as a requirement – a 'fact of life' but at the same time there is reluctance to see this as contributing to sustainable learning rather than to demonstrate improving standards at these assessments.

9.8 Looking back at the Askew *et al.* (2010) paper they find a study that places the most important factor for attainment as the content of the curriculum and pupils prior learning. Yet their report also stresses the need for a curriculum to recognise cultural influences and wider factors, for example they note that the Pacific Rim countries tend to focus more on algebraic manipulation. Yet in Hong Kong, algebra is taught in a more holistic way, while in England, more emphasis is placed on data handling, than algebra. The underlying finding emerging from the study is that a curriculum needs to consider the approach that is best suited to meet the skill requirements for each country, and that picking and choosing the best aspects of curriculum from each high performing country may not suit a different setting.

9.9 An important factor to introduce at this point is to state that the studies above are in the main, focused on the curriculum of mathematics alone, yet the evidence suggests that there is a need to integrate the teaching of numeracy across the curriculum as a whole. Returning to the report produced by the State of Victoria, we see their recognition of the need to give pupils the opportunity to apply numeracy principles across other

[17] Ages 10-11.

areas. They highlight mathematics as a single discipline, whereas 'numeracy' is cross-disciplinary impacting on numerous other areas and therefore all subject areas need to make a recognition of 'numeracy moments' where understanding basic principles of numeracy is a necessity. This is an important principle to note and the study makes reference to the need to integrate numeracy across all strands of the curriculum, this includes teaching numeracy in a way that may not look like mathematics by embedding numeracy requirements in a different context.

9.10 The issue of curriculum will also be considered within the themes of interventions and ICT and technology as a number of studies examine, the role that combining factors such as curriculum and technology can play on the teaching of numeracy.

**Box 3 - Key texts for curriculum factors**

Askew *et al* (2010) *Values and variables Mathematics education in high-performing countries*

Brown *et al* (2001) *Magic Bullets or Chimeras? Searching for Factors Characterising Effective Teachers and Effective Teaching in Numeracy Research*

Kyriacou and Goulding (2004) *A systematic review of the impact of the Daily Mathematics Lesson in enhancing pupil confidence and competence in early mathematics*

Slavin *et al* (2008) *Effective programs in elementary mathematics: A best-evidence synthesis.*

Williams, P. (2008) *Independent Review of Mathematics Teaching in Early Years Settings and Primary Schools,*

# 10. Theme 4: Interventions

10.1 In the literature, it is generally agreed that ‘interventions’, are approaches and methods that will be used when there are recognised problems or difficulties with a child’s understanding of numeracy, or in a child’s ability to understand numeracy teaching. In the majority of cases an intervention takes the form of additional teaching aimed at particular deficiencies, but there are a number of approaches that can be used.

10.2 One of the most widely cited authors on this issue is Ann Dowker. Her 2004 paper for the then UK Department of Education and Skills – ‘What Works for Children with Mathematical Difficulties?’ provides a very useful overview of the scope of the difficulties that children might face and also discusses approaches that might work. Her paper is a literature review of books, papers and research reports dealing with children's mathematical difficulties, and with the intervention techniques used to address them.

10.3 Dowker stresses the multiplicity of problems which need to be addressed for those with difficulties with numeracy as well as seeking to place a perspective on this. She makes the case that labelling a child as simply ‘bad at maths’ is incorrect, as it is most likely that a child will have specific issues with a certain aspect of mathematical learning be it memory for arithmetical facts, word problem-solving, representation of place value or the ability to solve multi-step arithmetic problems. Despite this variability, she highlights that one of the most common areas for difficulties to emerge is memory for arithmetical facts. She suggests that it is highly unlikely that a child will have problems with all of these areas, and the primary issue when looking to offer help for those with mathematical difficulty, is to identify the particular problems that each child is experiencing. Her work, which takes the form of a literature

review of research that has been conducted examining the effects of intervention practices, suggests that:

- Children's arithmetical difficulties are highly susceptible to intervention.
- Individualised work with children who are falling behind in arithmetic has a significant impact on their performance.
- The amount of time given to such individualised work does not, in many cases, need to be very large to be effective.
- Implementing intervention as early as is possible can lead to an increased likelihood of the intervention being successful.

10.4 Dowker (2004) reports that many children can experience mathematical difficulties and unlike literacy, numeracy difficulties can equally affect boys and girls. In addition, a significant number have specific difficulties. Mathematical problems can co-occur with dyslexia (but not always) and other learning difficulties. Interventions should be targeted early on in order to stop the mathematical difficulties affecting learning in other parts of the curriculum, and the child developing 'maths anxiety'.

10.5 Interventions which focus on the specific part of numeracy which the child is struggling with are likely to be the most effective. Types of interventions considered for efficacy by Dowker are classroom interventions such as: revision, streaming and setting; teaching assistants; pre-school programmes focusing on maths activities and games that include parents, designed to prevent difficulties occurring; computer-based interventions such as numeracy recovery and maths recovery; among other interventions developed as part of the English National Numeracy Strategy. It is beyond the scope of this REA to provide further specific detail on these interventions and their individual impact, however in conclusion:

> *"Children's arithmetical difficulties are highly susceptible to intervention. Individualized work with*

*children who are falling behind in arithmetic has a significant impact on their performance. The amount of time given to such individualized work does not, in many cases, need to be very large to be effective. Future goals should include further development and investigation of individualized and small group interventions, especially with younger children than those who have been most frequently studied so far."(Dowker 2004 p.v)*

10.6 The effectiveness of early intervention schemes is also mentioned in the Williams Review which cites research undertaken by Gross *et al* of KPMG for the 'Every Child a Chance Trust' which estimates that for every £1 spent on early intervention for the lowest attaining pupils, at least £12 will be saved long-term on the costs to the public purse. This review also provides recommendations as to the components of a successful intervention programme.

**Box 4 – Key Texts for Interventions**

Dowker, A. (2004) *What Works for Children with Mathematical Difficulties?*,

Williams, P. (2008) *Independent Review of Mathematics Teaching in Early Years Settings and Primary Schools,*

# 11. Theme 5: ICT and use of Technology

11.1 There are some examples in the literature of the impact of the effectiveness of a number of different technological factors including the use of IT, computer whiteboards and examples of the curriculum being tailored to encourage the use of new technologies such as learning using computers etc.

11.2 Askew and Brown (2003) find that there is no evidence to support the notion that significant beneficial effects can be observed from the use of computers to teach numeracy, although their literature on this subject is limited and they do go on to suggest that more use of computers for this purpose would appear to be justified to allow for a more wide ranging evaluation of impact.

11.3 Slavin *et al* (2008, 2009) did analyse the results of effectiveness of a programme of teaching that involved the use of Computer-Assisted Instruction (CAI). This method is used to supplement the more regular textbook-based learning and is a form of additional learning tailored to meet the students' individual needs. In this respect, it could also be considered as an 'intervention' (see Theme 4). This approach showed widely positive effects although as Slavin *et al.* highlight, this is a supplementary programme rather than a stand alone approach. Despite this, the positive effects are deemed to be moderate by the authors.

11.4 The National Numeracy Strategy proposed an increased use of ICT to help support teaching, although the systematic review by Kyriacou and Goulding and the Independent Review by Sir Peter Williams do not consider this element in any great detail. However, The Williams Review (2008) does make brief mention of the increasing use of interactive whiteboards without commenting on the role that they might play, or the impact that using this resource might have on teaching.

11.5 The report produced by the State of Victoria also offers a consideration of the use of these technologies in teaching numeracy:

> *"As a feature of the changing environment of schools, it is clear that technology will always be ahead of research. Newer technologies have the potential for enhancing engagement of students in learning mathematics. The impact of ICT on motivation and engagement has been researched, but the rapidly changing nature of ICT itself makes firm conclusions about its impact on achievement more difficult to reach." (State of Victoria 2009 p.40)*

11.6 This study reaches a similar conclusion to the aforementioned study by Askew and Brown in that the benefits or otherwise of use of technology are yet to be fully investigated or understood. While in the literature that this study uses there is an implicit assumption that the use of technology will see improvements the authors treat these claims with caution. To conclude their analysis of this the State of Victoria report suggests:

> *"The successful integration of ICT is also discussed by Raiti (2007), who argues that a change of culture is needed:*
> *Making sure that there are sufficient computers in your school won't necessarily encourage your teachers to use new technology. It's your school's learning culture which is more likely to determine whether desired improvements to teaching and learning can be effected through the integration of ICT*." (State of Victoria 2009 p.41)

11.7 This highlights the factor common to all of the literature; that it is hard to isolate individual factors in determining what is effective, rather a holistic and bespoke approach needs to be found.

**Box 5 – Key Texts for ICT and Use of Technology**

Askew, M., and Brown, M. (2003) *How do we Teach Children to be Numerate?* A professional user review of UK Research undertaken for the British Education Research Association.

Kyriacou C. and Goulding M. (2004) A systematic review of the impact of the Daily Mathematics Lesson in enhancing pupil confidence and competence in early mathematics.

Slavin, R E., Lake, C., and Groff, C. (2009). Effective programs in middle and high school mathematics: A best-evidence synthesis.

Slavin, R.E. and Lake, C. (2008). Effective programs in elementary mathematics: A best-evidence synthesis.

State of Victoria Department of Education and Early Childhood Development. (2009) *Numeracy in practice: teaching, learning and using mathematics.*

# 12. Concluding Remarks

12.1 Having considered the evidence obtained for the REA, the following key findings emerge in terms of the characteristics of programmes, and approaches that can be deemed to be most effective in teaching numeracy:

1. Curriculum factors
    - Integration of numeracy across the whole curriculum and not just being solely considered as ‘taught mathematics’.
    - A curriculum that is well-attuned to the country-specific skills need, and teaches basic concepts and principles that can be applied in later life outside of a purely mathematical context.
    - A curriculum which is developed to suit the specific cultural context.
    - A curriculum which is clearly aligned with its assessment regime.

2. Teaching practice
    - Collaborative teaching practices that encourage pupils to work in mixed ability groups with aspects of peer learning.
    - Scaffolding teaching practice.

3. Teachers’ professional development
    - Improving the levels of both subject specific knowledge and pedagogical content knowledge for teachers of maths, this can be considered at both the initial teacher training and also in combination with recognition of the importance of continuing professional development.

4. Interventions
    - Well designed, individually tailored intervention programmes for pupils that have mathematical difficulties, key to this is an appropriate system of early identification of difficulties.
    - Early intervention for those children who experience mathematical or numerical difficulties.
    - A dedicated maths specialist at school or local authority level.

5. ICT and technology
    - Tentative evidence that ICT and technology could have a part to play in effective numeracy teaching.

12.2 Having considered many factors that might contribute to the effective teaching of numeracy, there are still a number of issues that have been highlighted that pose problems when considering this REA. The primary issue here has been the availability of robust peer reviewed evidence to inform this REA. Ideally, the REA would be able to draw on only articles and journals that reviewed or synthesised empirical evidence from peer reviewed journals, however this is not always the case. The evidence reviewed here includes articles produced for governmental bodies or conference talks as well as studies produced using funding from foundations that may have their own reasons for requesting the work. An expansion of the existing evidence base that evaluates 'what works' for numeracy teaching, would be welcomed.

12.3 Despite this concern regarding the breadth of the evidence base, the review did find a number of articles that were deemed suitable for inclusion and the literature studied raises some important and interesting issues for policy development in this area. For instance the Askew *et al.* (2010) review for The Nuffield Foundation, raises a number of concerns regarding attempts to pick and choose successful elements of the school systems around the world that are regarded as being those to emulate. This includes the notion that even those countries that are consistently

ranked highest in the international comparisons, are raising questions as to the benefit of this. Does this mean that their systems are actually achieving the right things? To what end is this achievement helping or harming the country? On this point, South Korea is considering whether its pupils are merely becoming taught in ways that will encourage a higher ranking for instance.

12.4 Leading on from this is the realisation that even those systems that are high achievers, are always looking for ways to improve their systems and so a stable system that can be studied may prove to be elusive. Allied to this is the fact that there is also the impact from more difficult to measure factors, such as the culture of the country and the importance ascribed to education or certain aspects of education. The report highlights the fact that Finland, amongst others, utilises teaching practices that are considered 'traditional' and lacking in innovation yet still outperforms other nations that introduce the latest ideas in teaching practice. As the authors put it:

> *"National culture helps explain this – being born into a culture that highly values success in mathematics establishes a 'virtuous cycle' of continuing success. All too often schools and teachers are written about as if they somehow sit outside the overarching culture, attitudes and policies of their nation states. Obviously this is not the case, education systems are part of the broader cultural milieu. Culture, beliefs and dispositions have all come through strongly as powerful influences in learning mathematics*."
> (Askew *et al.* 2010 p.12)

12.5 While this may not be something that can be controlled, it is a factor that needs to be recognised if attempts are made to implement approaches that may have been successful elsewhere. It may be that factors outside of the remit of the policy or approach have contributed to the success, or otherwise, and that identifying the most relevant factor for success is impossible. The findings from the literature that was considered for this REA were often contradictory with differing views on the importance to be attached to the various components of numeracy teaching. What can be said to emerge from this however, is the realisation that it is not possible to consider each factor in isolation or to assume that a change in just one area will bring about success. A holistic and integrated approach that considers aspects of all of the identified themes tailored to the situation in Wales, would appear to be the option that offers the most likely route to successfully introducing an effective approach to the teaching of numeracy.

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# Glossary

**Subject knowledge** - also referred to as content knowledge this refers to a teacher's mathematical knowledge of the subject as a whole. Some researchers such as Ma (1999) cited in State of Victoria (2009) see this as "knowledge of basic mathematical ideas (i.e. the mathematical ideas that are pertinent to school mathematics)". This is also related to the notion that to fully explain mathematical ideas to his/her pupils a teacher must fully understand them him/herself to begin with.

**Subject pedagogic knowledge** - can also be referred to as pedagogical content knowledge and is related to a teacher's ability and knowledge of methods that translate and represent mathematical concepts and ideas into a suitable teaching approach that is appropriate for pupils of varying abilities to understand and learn.

**Conceptual understanding** - this form of teaching is recognised as being concerned with a teacher exploring with pupils their understanding of the basic principles underlying particular types of problem and embedding the concepts and techniques for solving the problem within this understanding.

**Procedural understanding** - this form of teaching is recognised as being focused on a teacher's explanation and demonstration of a procedure to solve a mathematical problem which the class then use to solve other problems.

# Appendix A

*Key Search Terms:*

'Numeracy', 'quantitative literacy', 'mathematical literacy' and:

Pedagogy
Techniques
System
Plans
Policies
Programmes
Interventions

in combination with -

Effectiveness
Evaluation
Implementation
What works
Approaches
Improvements
Teaching plan
Pilot programme
Strategy
Children
School age
Recovery

*Sources and Databases Searched:*

British Education Index, Education Resources Information Center, Ebsco Teacher's Reference Centre, National Foundation for Educational Research, Centre for Excellence in the Teaching of Mathematics, Evidence for Policy and Practice Information and Co-ordinating Centre, Educational Evidence Portal, Estyn, Ofsted, Organisation for Economic Co-operation and Development, United Nations Educational Scientific and Cultural Organization, British Society for Research into learning Mathematics, Department of Education, Department of Education Western Australia, Department of Education and Early Childhood, State of Victoria, Australian Government, Education, Government of Alberta, Economic and Social Research Council, University of Durham, University of Leeds, University of Sussex, National College for School Leadership

# Appendix B

*Inclusions and Exclusions*

Included:

The literature search will take in international literature but will be limited to journals and articles in English.
Literature on interventions that have not been fully evaluated will be considered but will face scrutiny at the quality assurance stage.
Literature and reports utilising quantitative and qualitative data will be considered subject to meeting qualifying criteria.
'Grey literature' that might not be peer reviewed but where methods are shown to be robust, will be considered for the Quality Assurance process.
Literature published since 2000 will be included.

Excluded:

Literature dealing with numeracy assessments and testing.
Literature not relating to children aged 5-14.
Newspaper and magazine articles or editorials.
Consultation responses.
Non-English articles.

# Appendix C

In order to grade the quality of the evidence that was obtained for inclusion in the REA an approach that was used by Kyriacou and Goulding (2004 p.15) was used.

Components were identified to help make explicit the process of apportioning different weights to the findings and conclusions of different studies. Such weights of evidence were based on the following:

A. Soundness of studies (internal methodological coherence) based upon the study only

B. Appropriateness of the research design and analysis used, for answering the review question.

C. Relevance of the study topic focus (from the sample, measures, scenario, or other indicator of the focus of the study) to the review question.

D. An overall weight taking account of A, B and C.

Each of these three components (A, B and C) was assessed as low, medium or high (scored 1 to 3 respectively) and an overall weighting for the study (composite D) was arrived at by taking the arithmetic mean of the three component assessments (rounded to the nearest whole number), so that a mean of 1, 2 and 3 yielded an overall weighting of low, medium and high respectively.

The table of results for each article included in this REA is provided below:

| Study Number | A Soundness of Studies (internal methodological coherence) | B Appropriateness of the research design and analysis used | C Relevance of the study topic focus to the review question | Mean | D | High / Medium / Low |
|---|---|---|---|---|---|---|
| 3 | 2 | 2 | 1 | 1.67 | 2 | Medium |
| 5 | 2 | 3 | 3 | 2.67 | 3 | High |
| 6 | 2 | 3 | 3 | 2.67 | 3 | High |
| 9 | 2 | 1 | 1 | 1.33 | 1 | Low |
| 10 | 1 | 2 | 2 | 1.67 | 2 | Medium |
| 17 | 1 | 1 | 3 | 1.67 | 2 | Medium |
| 19 | 2 | 2 | 2 | 2.00 | 2 | Medium |
| 21 | 1 | 1 | 2 | 1.33 | 1 | Low |
| 22 | 3 | 3 | 3 | 3.00 | 3 | High |
| 30 | 1 | 2 | 3 | 2.00 | 2 | Medium |
| 34 | 2 | 1 | 2 | 1.67 | 2 | Medium |
| 35 | 2 | 2 | 3 | 2.33 | 2 | Medium |
| 36 | 1 | 1 | 3 | 1.67 | 2 | Medium |
| 37 | 1 | 1 | 3 | 1.67 | 2 | Medium |

Study Numbers relate to the number assigned to the article at the initial search stage and carried forward through the data audit stages and refer to the articles as follows:

Studies graded as high quality:

5 - Slavin, R E., Lake, C., and Groff, C. (2009). Effective programs in middle and high school mathematics: A best-evidence synthesis. *Review of Educational Research,* 79 (2), pp 839-911.

6 - Slavin, R.E. and Lake, C. (2008). Effective programs in elementary mathematics: A best-evidence synthesis. *Review of Educational Research*, 78 (3) pp 427-515.

22 - Kyriacou C. and Goulding M. (2004) A systematic review of the impact of the Daily Mathematics Lesson in enhancing pupil confidence and competence in early mathematics. In Research Evidence in Education Library. London: EPPI-Centre, Social Science Research Unit, Institute of Education.

Studies graded as medium quality:

3 - Rakes, C.R., Valentine, J C., McGatha, M B., and Ronau, R N.(2010). Methods of Instructional Improvement in Algebra: A Systematic Review and Meta Analysis. *Review of Educational Research* 2010 80, pp 372-400.

17 - State of Victoria Department of Education and Early Childhood Development. (2009) *Numeracy in practice: teaching, learning and using mathematics.*

19 - Rudd, P., and Wade, P. (2006) *Evaluation of Renaissance Learning mathematics and reading programs in UK Specialist and feeder schools.*

30 - Askew, M., Hodgen, J., Hossain, S., and Bretscher, N., (2010) *Values and variables Mathematics education in high-performing countries*, Nuffield Foundation, London.

34 - Beverton, S., Harries, T., Gallanaugh, F. and Galloway, D. (2005) *Teaching Approaches to Promote Consistent Level 4 Performance in Key*

*Stage 2 English and Mathematics*, Department for Education and Skills, London.

35 - Dowker, A. (2004) *What Works for Children with Mathematical Difficulties?*, Department for Education and Skills, London.

36 - Askew, M., and Brown, M. (2003) *How do we Teach Children to be Numerate?* A professional user review of UK Research undertaken for the British Education Research Association.

37 - Mourshed, M., Chijioke, C., and Barber, M. (2010) *How the world's most improved school systems keep getting better.* Mckinsey.

Studies graded as low quality:

9 - Van Luit, J.E.H., and Schopman E.A.M., (2000) Improving Early Numeracy of Young Children with Special Educational Needs. *Remedial and Special Education,* 21, pp 27-40.

21 - Brown, M., Askew, M., Rhodes, V,. Denvir, H., Ranson, E,. and William, D,. (2001) *Magic Bullets or Chimeras? Searching for Factors Characterising Effective Teachers and Effective Teaching in Numeracy* Research Paper for – British Educational Research Association Annual Conference – Symposium on - Pedagogy and educational policy: modernising teaching or narrowing the agenda?