INTEGRATING EARLY ALGEBRAIC THINKING
IN THE MALAYSIAN PRIMARY SCHOOL
MATHEMATICS CURRICULUM

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Abstract
In recent years, there has been strong urge from mathematics
researchers to integrate algebra in primary school level. Introducing
algebra in primary school level does not mean teaching abstract form of x and y in primary school. Researchers
have argued that algebra underpinned in arithmetic and relates
many fundamental principles in primary school mathematics.
Classroom discussions and appropriate selection of tasks may
foster algebraic thinking. Teaching students to think algebraically
in early years of education will build a strong foundation to solve
algebra problems in later grades with conceptual understanding.
Algebraic thinking should be infused while teaching arithmetic.
Early algebraic thinking then bridge the gap between arithmetic
and algebra. Thus, it is essential to discuss about algebraic
thinking in primary school level to create awareness to educators
and curriculum developers in Malaysia. In line with the recent
international trend that emphasise on introducing algebraic
thinking in primary school, this concept paper presents importance
and theoretical perspective of algebraic thinking. This paper also
discussed the integration of algebraic thinking in international
mathematics curricula, elements of algebraic thinking that can
be incorporated in primary school level while teaching arithmetic
and present Malaysian primary school curriculum state in
infusing algebraic thinking.
INTRODUCTION

Throughout the years algebra has been depicted as a major complicated subject in school mathematics (Van Amerom, 2002). Poor performance of Malaysian students in algebra was well reflected in results of TIMSS (Trends in International Mathematics and Science Study). The results from TIMSS study provides a comprehensive view of Malaysian students’ achievement in algebra which can reflect the Malaysian education system and practice. Performance of Malaysian students in TIMSS especially in the domain of algebra has been always lower than outstanding Asian countries that have highest ranking in TIMSS such as Singapore, Korea, and Japan (Mullis, Martin, Foy, & Arora, 2012). Particularly, Table 1 shows that the Malaysian students’ achievement in domain of algebra in TIMSS that has been decreasing from 1999 to 2011.

Table 1

<table>
<thead>
<tr>
<th>Year</th>
<th>1999</th>
<th>2003</th>
<th>2007</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Scale Score</td>
<td>505</td>
<td>495</td>
<td>455</td>
<td>430</td>
</tr>
</tbody>
</table>

In Malaysia, formal algebra only begins in Form one (grade seven), secondary school (Kementerian Pendidikan Malaysia [KPM], 2011). From standard one to standard six in primary school the students were only exposed to arithmetic. Chapter seven of Form one mathematics text book introduces variables in the form of algebraic expressions. This case supports the claim made by Cai & Moyer (2008) that most of mathematics curricula separate arithmetic and algebra. The two topics are being treated as two distinct chapters. There is no connection between topic of arithmetic in primary school and formal algebra in secondary school.

However, National Council of Teachers of Mathematics (NCTM) in United States of America has been giving high priority for algebra beginning from pre-school level. NCTM asserted that from pre-school to grade 12, algebra is underpinned in arithmetic. The concept of function, for instance, can be taught through classroom discussions using numerical patterns in primary school level (National Council of Teachers of Mathematics [NCTM], 2000). Consequently, studies exploring the ability of primary school students to think algebraically begun to increase (English & Warren, 1998; Gan & Munirah, 2014; Warren, Cooper, & Lamb, 2006). In addition, studies have been conducted to explore kinds of instructional tasks which can develop
students’ ability to think algebraically in earlier grades together with evaluation of algebraic thinking skills that currently posed by primary school students (Haldar, 2014; Jacobs, Franke, Carpenter, Levi, & Battey, 2007; Rittle-Johnson & Alibali, 1999; Warren, 2003). International mathematics education field has recognised the importance of thinking algebraically in early years of school. Knowing the importance of algebraic thinking, this paper takes a step forward to present an overview of early algebraic thinking which acts as a bridge to connect arithmetic and algebra. This paper will create an awareness of algebraic thinking in early years to mathematics educators and curriculum developers in Malaysia.

**Importance of Early Algebraic Thinking**

Generally, in many countries mathematics curricula have separated arithmetic and algebra (Cai & Moyer, 2008; Carraher, Schliemann, Brizuela, & Earnest, 2006). Arithmetic always gets focus in primary school while algebra will be focused in middle and high schools. To be precise, primary school mathematics curriculum focuses on numeracy and calculation skills. Even though students excel in arithmetic, yet they find progression from arithmetic to algebra is tough because it needs a lot of complex adjustments (Kieran, 2004). Transition from arithmetic to algebra indicates “ending” of arithmetic” and “beginning” of algebra. This is where early algebraic thinking comes into play. It helps to improve the struggle established by strict separation of arithmetic and algebra (Carraher et al., 2006). Body of literature has identified in many mathematics curricula, arithmetic always has been separated from algebra. Thus, early algebraic thinking has been proposed to connect arithmetic and algebra.

Early algebraic thinking focused on conceptual understanding. Conceptual knowledge of arithmetic is important to build better understanding in later year of studies (Rittle-Johnson & Alibali, 1999). Relational thinking, for instance, should be emphasised when teaching arithmetic (Carpenter, Levi, Berman, & Pligge, 2005; Jacobs et al., 2007). $67 + 83 = \_ + 82$, for example, students can solve this problem by only computation. However, relational thinking may assist the students to identify that 82 is one less than 83 thus, adding one to 67 will solve this problem. Possessing such algebraic thinking skills to identify the relations to simplify problems are necessary for more complex problems in later grades of school. This kind of strategy described as relational thinking (Stephens, 2008). Relational thinking helps children to carry out computation in easier and efficient way rather than calculating in step-by-step sequence (Jacobs et al., 2007).
Generalisation is another important element of early algebraic thinking. It refers to the capability of identifying the basic number properties and generate a general statement (Hunter, 2013). Basic number properties are such as commutative, associative, distributive, zeroes and ones properties. Mathematics researchers have shown evidence that integrating generalisation in primary school can provide greater support for understanding of equations and variables which are two main aspects of algebra (Jacobs et al., 2007; Kaput, 2008). Generalisation in arithmetic context is focusing to relations between numbers and operations (Halder, 2014). 10 - 5 + 5 = 10, for instance, is one of many ways to represent number 10. It underpins the generalisation that there will be no effect on a number when add and subtract the same number. Generalisation also provides opportunities to develop more efficient strategies that embedded in conceptual knowledge (Jacobs et al., 2007). Jacobs and colleagues (2007) have proven, grade four and five students could demonstrate distributive property to solve $(9 \times 57) + 57 = 0$ by just calculating $10 \times 57$. This scenario demonstrates how understanding of general relationship of addition and multiplication supports generalisation development using conceptual understanding of number facts, addition and multiplication.

Warren (2003) has identified four central aspects to describe understanding of early algebraic thinking: “i) relationships between quantities, ii) group properties of operations, iii) relationships between the operations, iv) relationships across the quantities” (pp. 123-124). These aspects obviously show the relation of algebraic concepts and topics at middle and high school level. In middle and high schools teaching and learning, there is a common assumption that students are equipped with basic aspects based on previous experience in arithmetic. Therefore studies on early algebraic thinking suggesting that learning algebraic thinking in conjunction with arithmetic would benefit students to build stronger foundation for formal algebra learning.

Early algebraic thinking not only limited to aspects of arithmetic structures as explained by Warren (2003). It is also extends to patterns (Warren & Cooper, 2005; Warren, Cooper, & Lamb, 2006). Recognizing, extending and generalising patterns inevitable process of algebraic thinking. Symbolic and verbal generalisation required in order work with patterns. These skills prepare the students to see the connection between arithmetic (unique situation) and algebra (general situation).

**Theoretical Perspectives of Algebraic Thinking**

One of the theories that supports development of early algebraic thinking is Anderson's (1983) ACT-R framework. This is based on bigger picture
of information processing theory supports development of early algebraic thinking. ACT-R abbreviation of adaptive control of thought-rational framework of cognitive development concerns on how human cognition works. He asserted that learning takes place in three stages in memory. First stage is known as declarative then followed by knowledge compilation and final stage is procedural. Facts about a task such as knowledge about doing a subtraction is referred as declarative knowledge. Second stage is knowledge compilation which focuses on making information retrieval more efficient. Third stage, involves condition-action pairs which are called as productions (Anderson, 1983).

![Diagram of Memory Systems](image)

**Figure 1.**
A general framework for the ACT production system, identifying the major structural components and their interlinking processes. (Anderson, 1983, p. 19)

Besides this, three types of memories are involved too as shown in Figure 1. They are working, declarative and procedural memory. Short term memory which holds volatile elements known as working memory while long term memory which stores information permanently are declarative and procedural memories. Basic facts are stored in declarative memory. In the development of early algebraic thinking, for instance, basic facts are facts that related to arithmetic operations such as addition and multiplication (i.e.,
2 + 4 = 6, 3 × 5 = 15). In production memory, on the contrary, productions will take place. Productions are “condition-action pairs that specify that if a certain state occurs in working memory, then particular...actions should take place” (Anderson, 1987, p. 193). In the domain of early algebraic thinking, productions could be basic facts of arithmetic while the declarative knowledge would be actions related to conceptual understanding of arithmetic structure.

According to Anderson’s model, the environment produces the information and then goes into cognitive system through perception. Then it will be encoded and working memory will keeps it. This model implies as the student recognised the arithmetic operations which actually encoded in working memory. However merely doing this will be meaningless. Hence, the information in perception transmits to the declarative memory, where operations will become a signal for arithmetical activities. Due to limited storage capacity of working memory it leads to temporary storage of perception and enables faster retrieval. At the end, perceptions will be stored in declarative memory for longer time of duration. This is where other objects and events will be linked. This connection is the foundation to retrieve complex information from declarative memory.

Like in the case of figural pattern generalisation, first two or three figural patterns will be given and students will be required to find the subsequent or nth pattern. When first three terms of patterns were given and required to find the subsequent pattern, firstly working memory will receive this information and then will transmit to production memory. The production memory initiates the action of figuring out the subsequent pattern in the working memory when conditions for the pattern match with the subsequent pattern. Finally, as a result of cognitive activity the student will able to draw the subsequent pattern on the paper. On the other hand, more information about sequence of the pattern will be retrieved from the declarative memory and transmit to production memory through working memory if the conditions failed to meet the criteria of given pattern sequence. This information retrieval and matching condition-action pair process will loop until reaching a solution.

Declarative knowledge can have a negative effect on behavior (Anderson, 1983). If a learner obtained knowledge incorrectly or not processed correctly, an incorrect procedure can be performed. Children’s equal sign interpretation would be a good example to explain this because conceptual understanding of equal sign plays an important role as foundation for formal algebra (Jacobs et al., 2007; Kieran, 1981; Knuth, Alibali, McNeil, Weinberg, & Stephens, 2011). According to Kieran (1981), a relational symbol which indicates the sameness of both sides is referred as equal sign. In most cases, students often has operational understanding about equal sign,
like “add up the numbers” or “the answer” (McNeil & Alibali, 2005, p. 70). Operational understanding only enable students to compute and find correct answer (i.e., $5 + 3 = \_\_\_\_\_\_$), but this skill won’t lead to solve more complex problems in future. Lack of relational thinking hinder students to see the algebraic element of equality and they struggle to memorise algorithms to transform equations (Jacobs et al., 2007). Therefore it is important to ensure learner obtained knowledge correctly.

**Early Algebraic Thinking in International Mathematics Curricula**

Algebra not only been an obstacle for Malaysian students. It also has gained attention as an area to be improved internationally. Therefore, many countries have proposed and implemented early algebraic thinking in their mathematics curriculum. In Canada, patterning activities are included in the mathematics syllabus (Ministry of Education, 2005). Patterning activity begins from grade one. Students are required to identify, describe, extend, and create repeating patterns. The syllabus emphasise on exposing young children to repeating patterns and growing and shrinking patterns with concrete materials and pictorial displays. Students should be able to identify the properties of pattern and recognise relationships. Then students are exposed to equality and variables introduced as unknowns in grade five. The curriculum ensures students able to develop making generalisation ability and in-depth understanding of patterns and algebra. It is apparent that the curriculum introduces patterns from grade one and gradually introduces important concepts of algebra such as equality and variables in the later stages.

Same goes to mathematics curriculum in Australia. Patterns and algebra begin from stage 3 in New South Wales (NSW Department of Education and Training, 2012). It focuses on patterns and relationship in the early stage of primary school. The curriculum believes that to yield better understanding of algebra, students should be exposed to concepts of patterns, relationships, and unknowns in variety of contexts starting from primary school level. Functions gradually introduced to students by providing activities like “guess my rule”. It requires one student to develop own rule about numbers and another student should guess the rule. These kinds of class activities will foster algebraic thinking by developing conceptual understanding of number properties and arithmetic.

Likewise, in New Zealand, numbers and algebra begins from year one (Ministry of Education, 2007). The curriculum focuses on ability of students to create and continue sequential patterns based on ones, twos, fives and so on so forth. Later in year five the students were required to develop rule in
number patterns and work on unknowns. The tasks selection emphasised on the properties of operations. For example, the students requires to use multiplication facts to work with addition and multiplication (i.e., $42 \div 3$ is the same as $30 \div 3 = 10$ plus $12 \div 3 = 4$, so $42 \div 3 = 14$; or $42 \div 6 = 7$ (known fact), so $42 \div 3 = 14$).

Common Core State Standards in United States of America also has given very high priority for early algebraic thinking (National Governors Association Center for Best Practices and Council of Chief State School Officers [NGA], 2010). Students are being exposed to elements of algebraic thinking right from kindergarten to grade five. It focuses on pattern and numbers and operations properties. Students are expected to analyse the property of numbers and interpret numerical expression without computation. They also get exposed to functions informally by doing activities involving patterns and rules.

Preceding section discussed about the awareness and integration of algebraic thinking in primary school level mathematics curriculum internationally. In Malaysia, mathematics curriculum for year four for instance, has four strands namely; i) numbers and operations, ii) measurement and geometry, iii) relationships and algebra, and iv) statistics and probability (KPM, 2013). However, there is no any elements of early algebraic thinking. Introduction of ratio and proportion in year 4, 5, and 6 categorised into relationships and algebra strand. There is no any progressive introduction to algebra involving patterns, relationship, unknowns and properties of operations and numbers. Therefore, it is time to look at incorporating early algebraic thinking elements into Mathematics curriculum in primary school level.

What is Algebraic Thinking?

According to Kaput (2008), many agreed that strong symbolization and generalisation skills are essence of algebraic thinking. He classified these two distinct aspects into three strands namely; generalised arithmetic, modeling and functions. He defined symbolising aspect as “systematically symbolising generalisations of regularities and constraints” (p. 11), while he defined generalisation as “syntactically guided reasoning and actions on generalisations expressed in conventional symbol systems” (p. 11). Kaput’s categories comprised all aspects of algebraic thinking skills described in the literature of early algebraic thinking.

Generalised Arithmetic. Arithmetic proceeds from known to unknown while algebraic thinking is identifying the unknown and involves working with unknown quantities (Van Amerom, 2002). Algebraic thinking only can be developed through conceptual understanding of operations on
mathematical objects in place of procedural understanding which focuses on operations on numbers and producing an answer (Haldar, 2014; Hunter, 2013; Van Amerom, 2002). Generalised arithmetic can provide a space for in depth understanding of algebraic equations (Haldar, 2014). Generalised arithmetic involves generalisation about the arithmetic operations properties that hold true for all numbers. Kaput (2008) divided generalised arithmetic further into i) efficient numerical manipulation which involves simplifying calculations using number relations with compensation strategies and ii) generalisation which is utilising number properties like the commutative property, associative property and properties of ones, zero.

Modeling. Kaput (2008) defined modeling as “the application of a cluster of modeling languages both inside and outside of mathematics” (p. 11). It comprises tasks involving equivalence, open number sentences, and working with variables. According to Rittle-Johnson and colleagues (1999), many primary school students find \(3 + 4 = 5 + 2\) does not make sense. They had tough time to solve the equation presented in the form where operand was on the right side of equal sign (i.e., \(5 + 4 + 7 = 5 + \_\)). Relational thinking provides a conceptual understanding of equivalence that “the same as” while operational symbol only provides procedural understanding of equivalence that “do something”. Students should have the conceptual understanding of equal sign by seeing it as a symbol for relation not as an indicator to perform certain operations. Viewing equal sign as denoting to perform computation might be a hindrance for students to master algebraic thinking in later years of education. In algebra students will encounter algebraic equations which have operations on left and right of equal sign (i.e., \(6x - 10 = 4x + 2\)). Therefore, viewing equal sign as relational symbol is very important.

Open number sentences are not new to primary school students. They are always exposed to solving number sentences like “\(15 + \_ = 20\)” , “\(\_ + 8 = 12\)” , and “\(24 - \_ = 13\)” . Solving open number sentences are young students’ first exposure to algebra in early years (Carraher et al., 2006). These type of number sentences are algebraic in nature and expose students to develop their conceptual understanding of arithmetic operations.

Variable is very crucial aspect of algebra (English & Warren, 1998). Various researches have been carried out to investigate students reasoning about variables (Knuth et al., 2011). For young students’ understanding and relational view of equivalence also lead to better understanding of variables. They can readily solve the variable problems by thinking how many are needed to make the quantities same or the situation fair.

Stephens (2008) investigated year six and seven students’ progression from arithmetic to algebra in variable context using samples from Australia
and China. He used number sentences with one or two missing numbers to identify contingency of relational view on equality and the ability to work with equality with literal symbols. He used a questionnaire with three different types of questions. First type was number sentences with one missing unknown (i.e., $104 - 45 = o - 46$). Second type was arithmetical sentence with two unknowns (i.e., $72 - o = 75 - o$) and then the last type was similar to this except it includes literal symbols (i.e., $c - 7 = d - 10$). The results showed students who were used computational strategies in solving first type number sentences were unable to solve second and third type of number sentence. In contrast, students who were solved first type number sentences using relational strategies successfully solved second and third type questions. This shows a clear evidence that relational thinking is essential in dealing with unknowns. Students with relational view able to solve unknowns even before experiencing formal algebra.

Function. According to Kaput (2008), function is "the study of functions, relations, and joint variation" (p. 11). Functions often referred as middle and high school topics in algebra (NCTM, 2000; Warren & Cooper, 2005). Functions play an important role in most mathematical investigations and it also has been noted as difficult for many students in all grade levels (Warren, Cooper, & Lamb, 2006). However, researches have shown evidence that young students are able to demonstrate functional thinking (Warren & Cooper, 2005; Warren, Cooper, & Lamb, 2006).

Functional thinking can be introduced to young students using patterning activities. Patterns could be in figural or number form. Working with patterns is the student’s first experience with algebraic thinking (NCTM, 2000). Working with patterns is fostering the ability to recognise, describe, extend and create patterns (Warren & Cooper, 2005). Patterns are some series of figures or numbers that can be predicted some form of regularity. A “rule” could be constructed to define the series of figures or numbers.

Generally, students are exposed to repeating patterns right from preschool. Repeating pattern activities usually will be in the form of numerical (i.e., 2, 4, 7, 2, 4, 7, 2, 4, 7) or figural (i.e., , , , , ). Hence, these activities would be appropriate to introduce generalisation by asking them what would 10th or 20th figure or number would be (Warren & Cooper, 2008). The next level of patterning activities would be linear patterns where by it grow or shrink in predictable way. Often linear patterns presented in the form of input and output tables (Warren, Cooper, & Lamb, 2006). According to Warren and Cooper (2005), functional thinking also enables students to understand the operations and inverse relationship. When students are required to find the
input by using given “rule” and output, they will begin to explore further to look arithmetic as change and make link between operations.

The Integration of Algebraic Thinking in Malaysian Primary School Curriculum

In Malaysia, formal algebra only begins from first year of secondary school (i.e., Form one) (KPM, 2011). Not to deny Malaysian primary school text books do comprise some elements of algebraic thinking. The text books do provide open number sentences and numerical pattern exercises. For example, number patterns (pola nombor) sub topic included in chapter one of year four text book (KPM, 2013). Though comprise patterns activities, there is no emphasis given for development of algebraic thinking. These activities were limited to find subsequent or preceding one or two terms. While to infuse algebraic thinking, number patterns activities should provoke students to think of ‘rule’ involved and generalise it to find any arbitrary terms. The pattern activities should encourage students to perform near and far generalisation.

A case study conducted by Gan and Munirah (2014) in Sarawak using sample of five year five pupils, showed that they are able to exhibit some characteristics of algebraic thinking in patterns activities. They were able to look, recognise and extend the patterns but not beyond that. The results showed that they are yet to demonstrate generalisation skills which is the most important element of algebraic thinking. (Gan & Munirah, 2014). Hence, it is not surprising if the middle school students’ poor performance in TIMSS might be caused from of lack of algebraic thinking since primary school.

Malaysian primary school mathematics text books also have number sentences with missing numbers and introduce unknowns as amu. However, it is questionable how students solve those questions; by using mere memorisation of inverse operations or with conceptual understanding of operations and relational thinking. There is no evidence to show how Malaysian primary school students attempt these questions and how their teachers conduct discussion on these exercises. Therefore, it is difficult to say to what extent the primary school teachers in Malaysia currently infusing algebraic thinking in arithmetic.

To date very limited studies have been conducted in Malaysia in the area of early algebraic thinking. A study by Gan (2008) investigated 13 year five pupils’ ability to work with algebraic elements related problems and identified the evidence of the algebraic thinking capability in Sarawak. He conducted clinical interview by presenting the students with pattern generalisation and word problems involving unknown quantities. The findings showed that
Malaysian students are able to think algebraically. However, their ability to make generalisation, make use of various representation and symbol sense seemed to be confined and restricted to develop their algebraic thinking.

CONCLUSION

Preceding discussion explained introduction of algebraic thinking in primary school level plays an important role as determinant of success in later learning of formal algebra. Learning to view equal sign relationally, functional thinking by able to work with functions and in-depth understanding of operations properties build strong foundation for formal algebra. Based on Gan's (2008) findings, Malaysian primary school students yet to develop intensive ability to think algebraically. This inability might be resultant from traditional curriculum design and teaching and learning process which are only focuses on algorithms and computation with the ultimate aim being is to find answer.

Hence, this paper has reviewed and highlighted the urgency of algebraic thinking development in Malaysian primary school level. It has further provided essential strands and theoretical framework that could be integrated in Malaysian context. This review has shed some light on what is thinking algebraically in primary school level and how it can be integrated into curriculum. For an example, teaching compensation strategy in solving number sentences involving operations on both sides of equation (i.e., \( 5 + 2 = 4 + \_\)) will help the children to think relationally and simplify complex problems in formal algebra in future. It is time for local curriculum developers and educators to look into infusing algebraic thinking in curriculum and instructional strategies at primary school level.

REFERENCES


A Study of gamification on GeoGebra for remedial pupils in primary mathematics

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Abstract
Remedial pupils are often more engaged in their learning when the content delivered uses games-based-activities. This study integrated gamification using technology in learning mathematics which is one of the 21st century learning approaches. In this paper we report the results of a study on lessons using 2 learning games based on GeoGebra with reference to remedial pupils’ motivation in learning primary mathematics. The respondents consisted of 4 remedial pupils from a primary school in Selangor, Malaysia. Data were obtained through observation on lessons and questionnaire on students’ perception in gamification on GeoGebra. Observation by using video recording indicated that the sample showed high motivation in learning mathematics. Questionnaire result also showed students’ positive interest in using gamification on GeoGebra. In conclusion, this study found that using gamification on GeoGebra is highly effective in helping remedial pupils to learn primary mathematics besides increasing their motivation in learning. This study strongly recommends the implementation of gamification on GeoGebra to facilitate mathematics learning at the primary level especially in geometry.

Introduction
According to Clough [2] (cited in Kursus Asas Program Pemulihan Khas (Special Remedial Program)) [8] remedial students refers to those who are weak in reasoning, have less ability in making decision or conclusion and lack understanding of abstract items. Remedial learners also known as slow learners have below average skills and slower learning progress than the norm for their age. However, mentally retarded children are not included in the remedial category. This kind of students needs more interesting lesson or “hands on” activity in learning mathematics, for example games to increase their motivation and achievement. Nowadays, the world is adopting information and communications technology (ICT) especially in daily life. Therefore, a study of gamification by using Dynamic Geometry Software (DGS) for remedial pupils in primary mathematics is presented in this paper. We examine the pupils’ motivation on using gamification with GeoGebra through mathematics lesson.

Literature review
Sharifah [14] said that remedial pupils refer to those children who fail to understand the lesson and they might have high, medium or lower intelligence capability. However, mentally retarded pupils are not included in the category of remedial pupils. Remedial focus is on pupils who are unable to