SCAFFOLDING PRACTICES THAT ENHANCE MATHEMATICS LEARNING

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It is just over 25 years since Wood et al.(1976) introduced the idea of 'scaffolding' to represent the way children's learning can be supported. Despite problems, this metaphor has enduring attraction in the way it emphasises the intent to support a sound foundation with increasing independence for the learner as understanding becomes more secure. It has resonance with the widely accepted notion of construction and the constructivist paradigm for learning. The discussion that follows will characterise some classroom practices that can be identified as scaffolding, revisiting some of the original classifications, and identifying further scaffolding strategies with particular reference to mathematics learning.

BACKGROUND

The metaphor of scaffolding was introduced by Wood et al.(1976) to explore the nature of adult interactions in children's learning, in particular, the support that an adult provides in helping a child to learn how to perform a task that cannot be mastered alone. Such interactions are also informed by Vygotsky's (1978) concept of the Zone of Proximal Development, and writing based on the relationship between these two ideas have been extensively developed (Rogoff and Wertsch, 1984).

The notion of scaffolding is used to reflect the way support is adjusted as the child learns and is ultimately removed when the learner can 'stand alone'. Wood et al. identifying six key elements: recruitment - enlisting the learner's interest and adherence to the task; reduction in degrees of freedom - simplifying the task so that feedback is regulated and can be used for correction; direction maintenance - keeping the learner in pursuit of a particular objective; marking critical features - accentuating some and interpreting discrepancies; frustration control - responses to the learners emotional state and demonstration; or modelling a solution to a task. In discussing the last of these, a hint is given to the complexities that may not be apparent in this classification. In demonstrating or 'modelling' a solution to a task, for example, "the tutor is 'imitating' in idealised form an attempted solution tried (or assumed to be tried) by the tutee in the expectation that the learner will the 'imitate' it back in a more appropriate form" (Wood et al.1976:98).

Tharpe and Gallimore (1988) use the term '***assisted learning***' in relating educational practices with Vygotsky's notion of a Zone of Proximal Development. They identify six interdependent means of assisting performance: modelling - offering behaviour for imitation; contingency management - rewards and punishment arranged to follow on behaviour; feeding back - information resulting from experiences; instructing - calling for specific action; questioning - calling for linguistic response; cognitive structuring - providing explanations and belief structures that organise and justify. Of these they claim cognitive structuring, which provides a 'structure for thinking and acting', is the most comprehensive and most 'intuitively obvious'. They note, however, 'study after study has documented the absence in classrooms of this fundamental tool: assistance provided by more capable others that is responsive to goal-directed activities' (Tharpe et al. 1988: 42).

The dependence on adult interaction is qualified by Rogoff and colleagues who use the notion of '***guided participation***' and regard children's development as 'occurring through their active participation in culturally structured activity with the guidance, support and challenge of companions who vary in skills and status' (Rogoff et al. 1993:5). They noted two patterns of interactive behaviour: one in which the adult structures children's learning by organising children's attention, motivation and involvement and by providing lessons taken from the context of an ongoing activity; the other in which children take primary responsibility for learning by managing their own attention, motivation and participation with adults providing assistance that is more responsive than directive.

SCAFFOLDING AND CLASSROOM PRACTICES

Research that attempts to characterise scaffolding practices in the classroom has suggested that teaching situations are more complex than small group settings and 'contingent responding requires a detailed understanding of the learner's history, the immediate task and the teaching strategies needed to move on' (Hobsbaum et al.1996). Despite this difficulty they support the notion of scaffolding and characterise key elements identified in a Reading Recovery scheme:

- a measured amount of support without reducing the child's initiative;
- careful selection of the task at just the right level of difficulty with right balance of general ease but some challenge;
- child must be able to make sense of task using every available source of information;
- strategies made explicit - drawing explicit attention to strategies and processes.

(Hobsbaum et al.1996: 22).

In their analysis of 'talk cycles' they found 'the predominant teacher strategy, by a long margin, for leading the move onto the next word cycle was telling' (p26). Teachers did, however, 'structure the internal setting so that the child develops increasingly more complex actions independently'.

In studying classroom teaching sequences in mathematics, science, and design and technology, Bliss et al.(1996) looked for instances of scaffolding but report 'a relative absence of scaffolding in most lessons'. Some '*actual scaffolds*' are identified as: approval, encouragement, structuring work, and organising people. '*Props scaffolds*' are also identified where the teacher provides a suggestion that will help pupils throughout the task and '*localised scaffolds*' providing specific help 'where a teacher finds it difficult to help the pupil with an overall idea or concept simply because it is too large and complex'. Two further scaffolds which Bliss et al. suggest were 'really more like cueing' were *step-by-step* or *foothold* scaffolds (often in a series of questions) and *hints and slots* scaffolds (narrowing questions until only one answer fits). They report few actual scaffolds and suggest reasons for absence of scaffolds in 4 categories: pseudo-interactions or bypassing (which accounted for the majority of classroom instances recorded); scaffolding precluded by directive teaching; scaffolding excluded by initiative being given to the pupils; conditions for scaffolding present but not noticed by the teacher (Bliss et al.1996:46).

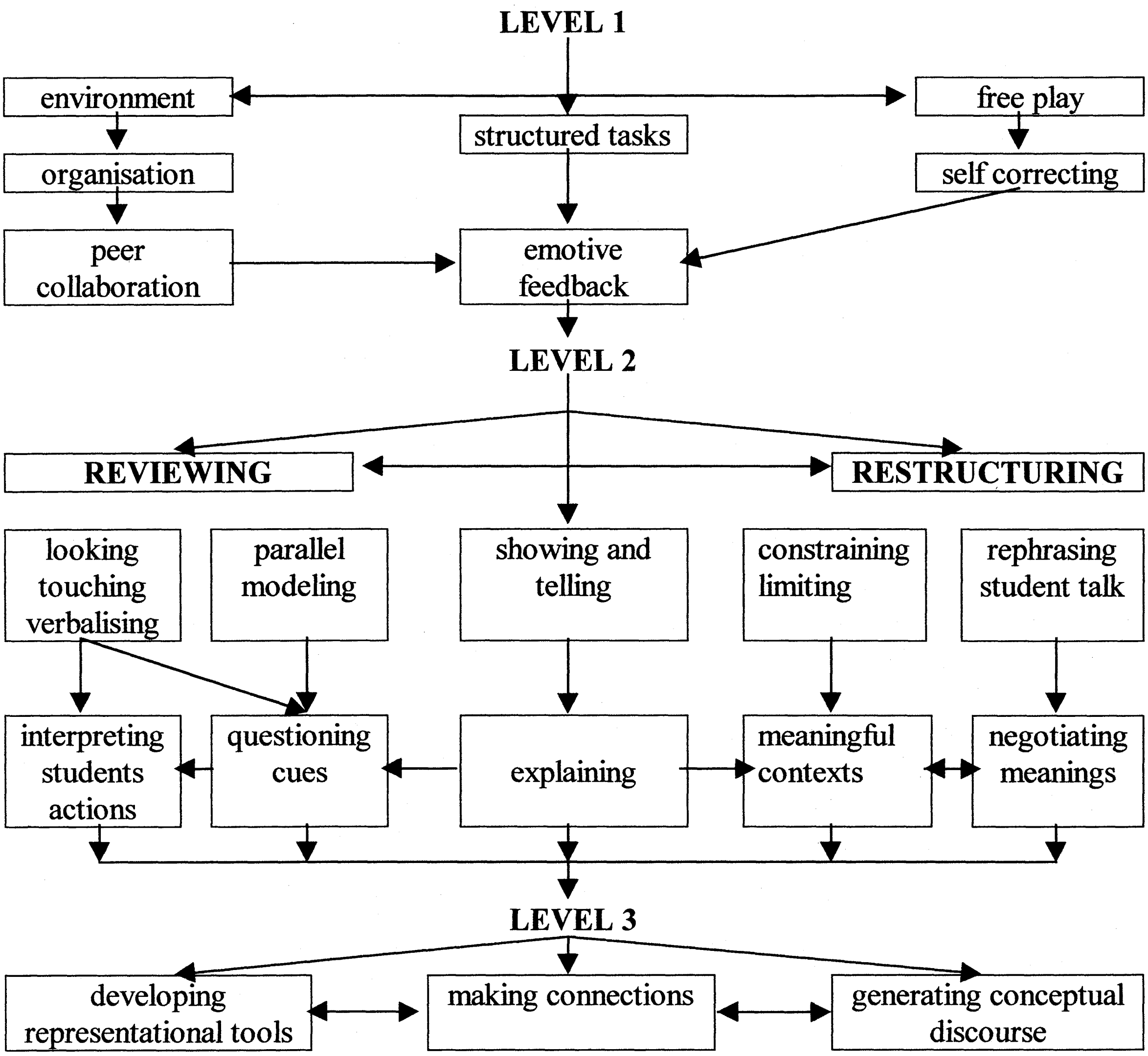
Despite the negative connotations of the latter study, teachers are integral to the learning process and the following discussion will identify strategies that can be classed as scaffolding, with illustrations taken from research studies in mathematics. Some different aspects of the scaffolding process will be illustrated in relation to geometry in the early years of schooling and arithmetic in later elementary years.

IDENTIFIABLE SCAFFOLDING PROCESSES

Some scaffolding practices are found in every classroom while others may be lacking completely. The classroom environment, for example, is prepared by a teacher as a resource for learning with materials available for the students to see, touch and use in their work. Other forms of scaffolding that may be less evident include peer interactions which is minimised where students work from texts in class and at home. Explaining and questioning will be common in most teaching approaches but analysis of these practices shows complex variations in the balance of interactions intended to support pupils' learning. In the following discussion, scaffolding strategies will be identified with further classification as *reviewing* and *restructuring* in a hierarchical inter-relationship.

Teaching strategies that focus on the provisions for the learning environment but do not directly relate to interactions between students and teacher are classed as *Level 1* scaffolding. Also classified at this level will be emotive interactions that are general in their nature. *Level 2* involves direct interactions between teachers and students specifically focused on the task in hand. Such strategies vary from direct instruction - showing and telling - to more collaborative meaning making. At *Level 3* the fundamental aim is to establish connections between what students have within their experiences and new mathematics to be learned. Mathematical thinking is supported through conceptual discourse and the establishment of representations. At any stage, mathematical learning is enhanced by scaffolding at each of these levels, and the following hierarchy reflects not only the progressive (and often circular) supporting strategies that can be used, but also the way effective interactions may be bypassed in more direct teaching approaches.

Figure 1: Teacher Strategies for Scaffolding Learning



LEVEL 1 SCAFFOLDING

Before interacting with the children, teachers will create an environment for learning with a choice of wall displays, puzzles, tasks, appropriate tools and classroom organisation (Tharpe et al.1988). This form of scaffolding has not always been explicitly acknowledged in research (e.g. Bliss et al.1996) but is a crucial element of any school practice. Opportunities for using building blocks in *free play*, for example, results in improved performance on geometry tasks with this performance further enhanced by interactions with a 'more experienced other' (Wood et al.1976; Coltman et al.2002). *Self-correcting* elements provide feedback that supports pupils, not only in finding a solution, but also in reflecting on the processes involved in such a solution and so becoming self regulating in their actions (Tharpe et al.1988).

The tasks that teachers select require *organisational* considerations, for example, appropriate *sequencing* and *pacing,* and groupings for *peer collaboration.* Light and Littleton (1999) report 'compelling evidence for the benefits in terms of learning of peer collaboration' and establish that peer collaboration need not involve 'a more experienced other'. Doise et al.(1984) showed that children of slightly different pre-test level, working together in pairs or threes, tended to perform at a higher level when working as a group than children working alone and this benefit carried over to post-test performances. Large differences in terms of the children's pre-test levels were associated with less progress than small differences in initial ability.

Also at Level 1, but less specific to mathematics learning is *emotive feedback* like gaining individual's attention or offering praise. Bliss et al. included 'approval (and) encouragement' in the majority of what they called 'actual scaffolds' along with 'structuring work' and 'organising people' (Bliss et al.1996: 47).

LEVEL 2 SCAFFOLDING

Mathematics can be presented as a series of skills and processes that are known to the teacher and transmitted to students through showing and telling. On the other hand, students can be more involved in the development of mathematical knowledge through interactions that progressively develop their own understandings.

Showing, Telling and Explaining

Showing and telling need little introduction as they have been traditional in classroom teaching for generations and continue to dominate classroom practice (Hobsbaum et al.1996; Pimm, 1987). With this strategy teachers retained control and structure conversations to take account of the 'next step' they have planned. Students can make their own sense of instruction sometimes in very different ways from the teacher (Bliss et al.1996: 41). Closely related to the classroom practice of 'showing and telling' is the notion of 'explaining' where the teacher amplifies a process or concept, or elaborates why solutions are inaccurate or inappropriate. In contrast to this teaching approach which is built upon teachers' explanations, social norms can be established in the classroom where the students actively participate by explaining and justifying their own thinking (Cobb et al., 1991). Askew et al.(1997) found that for effective teaching it is crucial to encourage pupils to 'develop strategies and networks of ideas by being challenged to think, through explaining, listening and problem solving'.

Scaffolding that goes beyond showing, telling and explaining

In contrast to telling students what to do and how to think about a problem, there are practices which provide support for developing students' own understanding of mathematics. <u>REVIEWING</u> relates to interactions that: encourage students to look, touch and verbalise; use questions, cues and parallel modeling; interpret student actions. <u>RESTRUCTURING</u> involves teachers making adaptations: by constraining or limiting the tasks; by giving meaningful contexts; by sensitively rephrasing students' talk and solutions; and by negotiating meanings.

Looking, touching, verbalising, and parallel modelling

In arithmetic teaching the encouragement to "tell me what you did" can help a student to be self correcting or more efficient. 'It seems that the act of attempting to express their thoughts aloud in words has helped pupils to clarify and organise the thoughts themselves' (Pimm 1987:23). Handling materials and verbalising observations can provide a different orientation and lead to better understanding of mathematical tasks (Coltman et al. 2002). When such reflective interactions are not sufficient there can be a temptation to 'tell' a solution. However, an alternative strategy, evident in studies of geometric block tasks, can be 'parallel modeling' where an equivalent task is demonstrated that helps develop transferable skills in the student (Coltman et al.2002).

Questioning

Pimm (1987) discusses a framework of questioning which 'locks the teacher into 'center stage', acting as controller as well as *heavily* influencing the *types* and range of spoken pupil contributions in class. Tharpe et al.(1988) note that 'it is easy to feel "in sync" with the students when the yes/no answers flow smoothly.....(when) she (the teacher) has inadvertently 'fed' them lines rather than assisting comprehension'. At the other extreme, questions can be posed that encourage the children to construct their own mathematical understanding and to determine independently whether they have reached mathematically valid solutions. Chappell et al.(1999) propose that 'when we modify the questions that we ask ... our assessment of students' thinking refines our instructional practice and indicates to students that we value their ability to communicate about mathematics'.

Interpreting students actions/ Making strategies explicit

Wood et al. (1976) note that 'the learner must be able to *recognise* a solution to a particular class of problems before he is himself able to produce the steps leading to it without assistance' (p90). This recognition of the relevance of actions can involve a teacher interpreting students actions and making strategies explicit. Hobsbaum et al. include 'drawing explicit attention to strategies and processes (which) provides a model of behavioral regulation for the learner, which may become internalised, a 'voice in the head' for future situations'(Hobsbaum1996: 22).

Constraining, limiting and simplifying

In Wood et al.'s original paper one element scaffolding was identified as: '*reduction in degrees of freedom* - simplifying the task so that feedback is regulated to a level which could be used for correction'. An example is given in reducing from three blocks in a repeating sequence to two blocks (Coltman et al. 2002) or simplifying the numbers in a calculation can make a task accessible before building towards the more complex task.

Identifying meaningful contexts

Meaningful contexts can help students find solutions to tasks where they cannot solve related abstract problems. Young children can more successfully solve tasks given in context and then transfer their learning back to abstract tasks (Coltman et al. 2002). In arithmetic, the shift from an abstract calculation, for example, '6 ÷ 12 = ', to a contextual setting: "Six pizzas are to be shared among 12 people. How much does each person get?", can take a problem from inaccessibility to the construction of a meaningful solution (Anghileri 2000).

Re-phrasing students talk and negotiating meanings

As a teacher pays close attention to the utterances of pupils, many 'spoken formulations and revisions will often be required before an acceptable and stable expression can be agreed upon by all participants' (Pimm 87:23). The teacher's role is to highlight processes involved in solutions, sometimes re-describing students efforts and making clear the mathematical aspects that are most valued. Considerable sensitivity may be needed to 'unpick' the essence of students' talk, rephrasing where necessary to make ideas clearer without losing the intended meaning, and negotiating new meanings to establish mathematically valid understandings (Anghileri 1995).

LEVEL 3 SCAFFOLDING

Making connections

Through both REVIEWING and RESTRUCTURING students can be supported in making connections with their previous experiences. Askew et al.(1997) use the term '*connectionist*' to characterise highly effective teachers who believe that pupils develop strategies and networks of ideas with teacher interventions to connect existing understandings with mathematics to be learned. Lack of connections can hamper progress. In arithmetic, for example, discontinuity between informal approaches and taught procedures can result in little progress while teaching approaches that develop progressive connections lead to better improvements (Anghileri 2000).

Developing representational tools

Much of mathematical learning relates to the interpretation and use of systems of images, words and symbols. Such representations, in addition to providing a means of communication, can also be developed as tools for structuring knowledge and to index the systems in which they arise. Cuoco et al. present a wide range of perspectives about the nature and purposes of representation with distinctions made between external representations (marks on paper, geometric sketches, equations etc.) and internal representations (images we create in our minds for mathematical objects and processes) (Cuoco et al. 2001:x). With teacher guidance, a symbolic record can facilitate discussions, and representations including pictures, diagrams chart and tables can be used not only for recording but as tools for thinking.

Generating conceptual discourse

Teachers play a vital role in shaping classroom discourse through signals they send about the knowledge and ways of thinking that are valued. Cobb et al. (1991) identify classroom discourse as critical in supporting the students' development and focus on 2 characteristics that relate specifically to math learning: the norms and standards for what counts as acceptable math explanation (conceptual not computational) and the content of the whole class discussion. With a conceptual orientation students are likely to engage in longer, more meaningful discussions and meanings come to be shared as each individual engages in the communal act of making mathematical meanings.

SUMMARY

This brief review of scaffolding processes is an attempt to identify a hierarchy of classroom interactions that can enhance mathematics learning by diverging from the narrow approach that has been typical in the past.

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