STUDYING CHANGE PROCESSES IN PRIMARY SCHOOL ARITHMETIC PROBLEM SOLVING: ISSUES IN COMBINING METHODOLOGIES

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In studying changes to children's successful strategies while solving arithmetic tasks with primary school children, two methodological approaches were combined: the microgenetic method and the clinical method of interviewing. This paper discusses the ways in which these approaches were combined in supporting the realisation of the project. The paper presents outcomes which illustrate the type of changes observed at the various levels of children's problem solving activity within a specific type of addition task, and argues that the particular methodological combination is suitable and effective in studying the process of procedural and conceptual change in mathematics problem solving.

Introduction

The aim of this article is to show how two research methods, the microgenetic method and the clinical interview, each of which has been particularly useful in the study of qualitative and quantitative aspects of children's understanding and problem solving in mathematics, can be combined to offer additional insights into understanding the *process of change* in children's problem-solving strategies in arithmetic.

Understanding change in cognition is important in developing instructional techniques that facilitate and enhance children's learning and development. Much research has focused, quite understandably, on analyses of cognitive changes that occur macro-developmentally, that is over an extended period of time. Such research has been carried out by applying methods of comparing the performance of children of different ages in specific domains of learning and development. In the past few years there has been an increasing interest in studying *how* change occurs and which mechanisms produce such change (Miller, 1992). The study of change processes in children's learning and development has been a particularly challenging task because of the difficulty of formulating appropriate methods.

The value of applying the microgenetic, or micro-developmental, method of research when the *process* of cognitive change is the focus has long been acknowledged. The term *microgenetic* originates from Vygotsky's genetic method of analysis, while the term *microdevelopmental* has its roots in the Piagetian tradition. Although these two schools of thought in developmental psychology agree on little else, in this case the difference in terminology does not imply any significant difference in meaning. Microgenetic/microdevelopmental research has proved to be well suited to studying the *process*, rather than the products, of cognitive change because change is studied moment-by-moment, during a short time, i.e. a number of experimental sessions over

weeks or months (Kuhn, 1995). In recent years this method, in particular, has increasingly been used to investigate the process of change in children's problem solving strategies (Miller and Aloise-Young, 1996; Bjorklund and Hubertz, 2004).

Another well-established method is the clinical interview, a research tool originating in Piaget's investigations of children's thinking and reasoning. More recently, a *revised clinical interview* procedure has been proposed by Ginsburg, *et al*. (1983) in which the form of clinical interview involves concrete objects and a problem to be solved. This type of the method has been used substantially in research that aims at exploring young children's mathematical reasoning (e.g. Cumming and Elkins, 1999; Goldin 2000).

The paper outlines the main characteristics of the two methods and argues for the efficiency of a particular methodological combination. Evidence for this approach comes from the outcomes of a study which aimed to explore changes that children introduce to their successful problem-solving approaches while being engaged in solving a specific type of addition task more than once.

The microgenetic method: general characteristics

Within the Soviet theory of activity, it has long been emphasised that any mental function must be studied in a process of development. In Vygotsky's microgenetic analysis the investigator has the opportunity to observe how individuals become familiar with a skill, concept or strategy within set observational period. Recently, Siegler and his colleagues (1991, 1995) presented a detailed account of microgenetic methods and revitalised the approach, mainly by applying it in the domain of learning arithmetic. Siegler's (1996) prime consideration is that in most studies of cognitive development, the changes that occur are *inferred* by comparing behaviour before and after the change. This indirect method cannot depict changes in children's thinking that do not follow the most conceivable route. For example, Karmiloff-Smith's microgenetic research (1984) revealed that representational growth frequently followed success rather than, necessarily, failure (as is often supposed to be the case), and also revealed short-lived regressions that would not have been detected without a close examination of the performance as it was changing. Siegler and Crowley (1991) highlight the following key properties that define the microgenetic approach:

- Observations of individual children span the entire period of rapid change in the domain of interest. That is, from the beginning of the change to the time at which it reaches a relative stable state.
- The density of observations is high relative to the rate of change of the phenomenon.
- Observed behaviour is subjected to intensive trial-by-trial analysis with the goal of inferring the processes that give rise to both quantitative and qualitative aspects of change. (ibid., p. 606).

Dense observations of behaviour are followed by intensive analysis of both qualitative and quantitative aspects of change. This allows the generation of differentiated descriptions of particular changes, and makes microgenetic methods highly pertinent as a source of information about how change occurs (Siegler, 1996).

The clinical interview: general characteristics

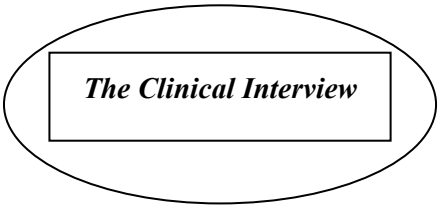
In the clinical method, 'revised' to involve a specific task to be solved and specific material, the researcher poses verbal questions related to the situation. The procedure aims at eliciting intellectual activities, accounting for the nature and organisation of cognitive processes, and evaluating the level of the child's cognitive competence (Ginsburg *et al*., 1983).

The main characteristics/advantages of this method, which make it highly pertinent to the study of changes in children's thinking within a microgenetic design, relate to the fact that the manipulation of physical materials, and the child's action upon them, reveal to the researcher information about the child's thinking and reasoning when the child's verbal responses are obscure. In addition, designing situations that involve not only verbal questions but also some concrete material to work on, allows the researcher to create an experiment, or microworld, that is both conceptually rich and meaningful to the child (Ackermann, 1995). The clinical method, as an open ended process, gives room for unexpected and insightful statements from children and this flexibility allows the thorough exploration of children's thinking processes, in addition to an account of the results of that thinking (Clement, 2000). A further, and important, advantage of the clinical method is that the conversational and playful character of the setting motivates both the researcher and the children within a microgenetic design, given that such a design has a high cost in terms of time and effort due to the dense sampling of behaviours over time.

design of the study: AN example of method integration

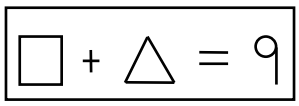
The aim of the study was to explore the ways by which children change and develop their successful problem solving strategies, and, furthermore, to explore the degree of procedural and conceptual control that children have over the task and over their evolving strategies during the 'after success phase' in their problem solving activity.

The sample for the study consisted of ten 5-6 year old children, selected from a Year 1 class from an infant school in southern England. Given that the study focused on children's evolving strategies during a relatively limited number of sessions, and also on changes that children introduce to their problem solving behaviour *after success*, children most competent in addition were selected to participate. Thus, less time would be devoted to considering arithmetical misunderstandings and errors. The diagram on the left illustrates the methodological approach.



The microgenetic method was used as the overall framework of research and approach to investigation.

That is, changes in children's successful strategies were studied by observing children's problem solving behaviour very densely, in the course of a sequence of sessions close in time, during which children were individually involved in solving a specific form of addition task more than once, and after they had already been successful in solving that form of task. The clinical interview was the research tool. It involved an arithmetic task which required the children to find all the possible pairs of number bonds that add up to a specific number each time, i.e. the 'target' number.



In one of the tasks, a pile of cards with incomplete number sentences, such as the one on the left, was at children's disposal. Children had to pick up one card at a time, and complete the number bond until there were no more possible ways to do so. The produced number bonds were put in a column. The task was repeated with different 'target' numbers which increased gradually. On each occasion the children were asked to describe how they completed each solution step and to explain the rationale and effectiveness of the strategy used. Children's overt behaviour (verbalisations, movements, hesitations) was video-recorded and analysed.

While the need to apply the microgenetic method was inherent in the study (since the focus was on changes and transformations that occur within the micro-context of a task over the course of a number of sessions), the application of the clinical method of interviewing was appropriate because the aims that the clinical method serves (such as the identification of children's behavioural strategies, the study of short term effects on a child's performance in the course of a session, and the exploration of the depth of conceptual understanding which at different moments of the solution process supports children's strategies) are consistent with the aims of the microgenetic method as used in this study.

after success change processes: Main Outcomes

The methodological combination applied allowed the observation of different types of change at two levels of the problem solving procedure, as Table 1 illustrates.

Level A: At this level, children moved from a 'step by step' approach, where the production of each number bond was considered as a separate problem and a variety of methods was applied at each solution step (e.g. recall from memory, counting, use of number line), to the development of an organisational strategy, the 'ordering' strategy, which allowed children to solve the problem without the need for any type of computation, simply by choosing the numbers to use as first or second addends in ascending or descending order correspondingly.

Level B: At this level, changes observed were either at the procedural facet of a method/strategy (that is the procedural application), or at the conceptual facet of a method/strategy. Changes at the conceptual facet were inferred based on the type of explanations that children provided for the arithmetical relationships that sustained the application of a specific method or strategy. There was a constant interplay of

changes observed between the two levels of the problem-solving situation, and between the procedural and conceptual facet of methods/strategy at level B.

Table 1: Levels at which changes were observed and types of change.

Level A	Level B
Changes introduced to the overall problem solving approach	**Changes introduced within methods/organisational strategy**
From: **'Step by Step'** Initially, each solution step was approached as a separate problem. Different methods were applied to different steps. To: **Organisational Strategy** Applied to the whole of the solution process.	2 Facets of methods / strategy change **Procedural** **Conceptual** **Gradual change** From: Low degree of control-knowledge accessibility and explicitness. To: High degree of control-knowledge accessibility and explicitness.

At each of the two levels at which changes were observed, different children followed different itineraries of change. Also, at the end of the study, different children reached various degrees of procedural and conceptual control over their own successful strategy and over the aspects of the problem. However, *all* the children reached one destination: the development of an organisational/economical-in-effort-strategy which allowed them to increase the control they had over their own problem solving approach and over the task (see Voutsina and Jones, 2003).

Conclusions

The combination of the microgenetic method with the clinical method of interviewing proved to be particularly effective in this study as it allowed the observation and study of very subtle changes that occur at the multiple levels of a very complicated situation such as a problem-solving situation. Furthermore, the particular methodological integration produced very rich data which allowed the researcher to make inferences about the procedural and conceptual aspects of the change process in children's arithmetic problem solving. Also, the use of the clinical method as research tool in a microgenetic study was very effective in keeping the children interested and motivated during a very effortful and time-consuming research process. However, it should be emphasised that the combination of the microgenetic method with the clinical method worked very well within the specific type of microgenetic design utilised for the purposes of this research. It needs to be

tested whether the clinical interview can be fruitfully integrated in other types of microgenetic research.

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