DEVELOPING A CLINICAL INTERVIEW PROTOCOL TO ASSESS CHILDREN'S UNDERSTANDING OF PROBABILITY

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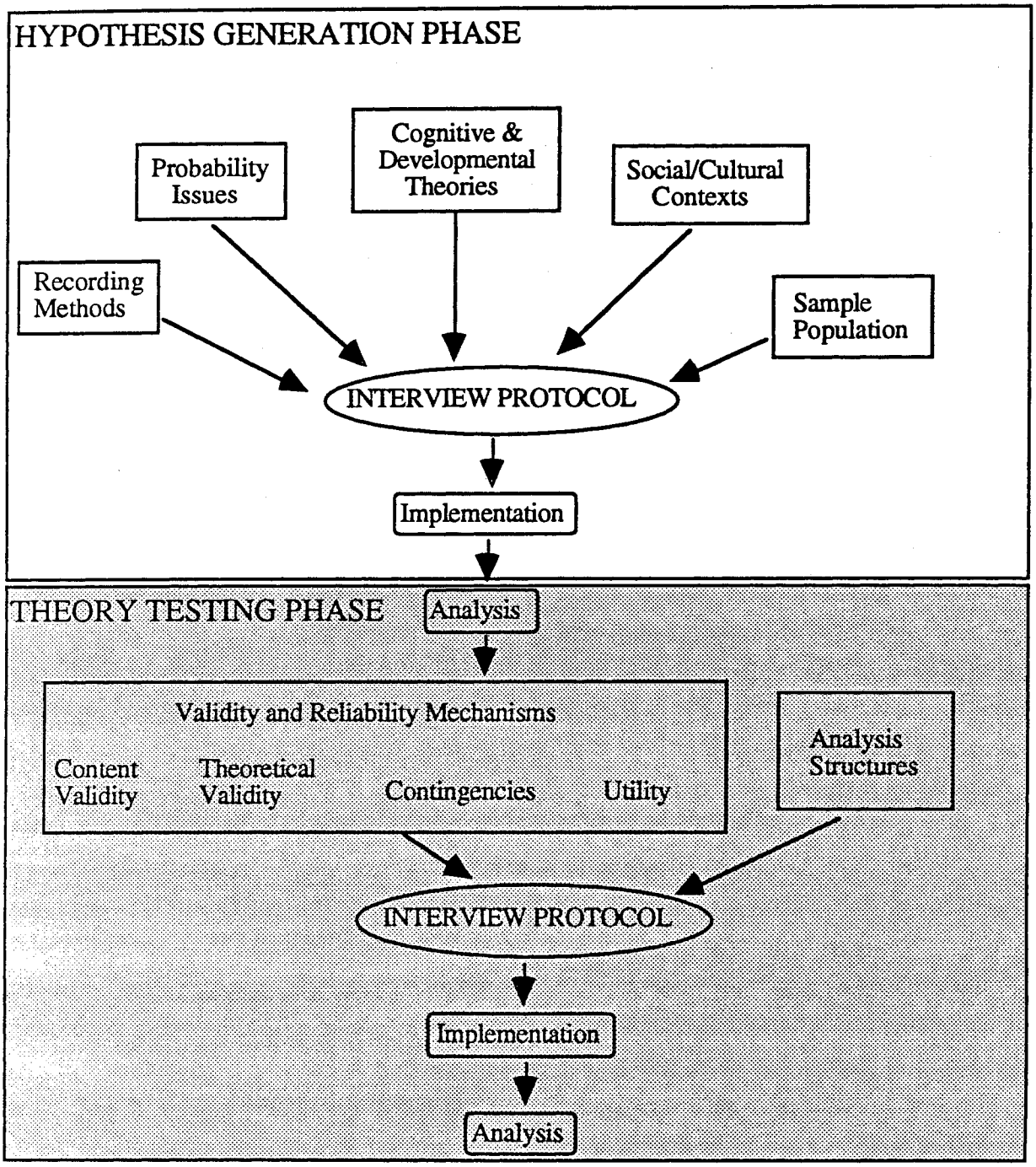
This paper presents a model devised for the development of a clinical interview protocol to assess children's understanding of probability. The model is based on the work of both Australian and overseas researchers, and attempts to address the many issues that need to be considered when undertaking research of this nature. As the research project concerned is in its early stages, it is hoped that the paper will stimulate some debate of the theoretical issues and draw suggestions for the development of interview tasks.

At present the topic of 'Chance' is not included in the NSW Mathematics K-6 Syllabus. However, it is inevitable that it will soon be incorporated. Although there has been some ongoing research overseas, and an increasing interest in Probability research in Australia, a great deal of investigation into children's understanding of early probabilistic concepts still needs to be done. This is of particular concern because of the substantial evidence of widespread misconceptions regarding probability in older students and adults, and the difficulty experienced by people in applying probabilistic notions to solve problems. Decisions are being made about how to teach probability to young children with insufficient knowledge about what children already understand or misunderstand in this area.

One technique which is finding increasing acceptance as a research method for the study of mathematical learning, mathematical thinking and problem solving is Piaget's *'method clinique'* , or simply 'clinical interview'. As with all research, it is important that researchers engaging in clinical investigation be able to articulate the relationships between their research and its theoretical base and justify the methods or techniques employed. The process model presented in this paper attempts to provide a framework to assist the researcher to achieve these requirements. The two main purposes of conducting such an interview are to observe mathematical behaviour and to draw inferences from observations about the child's cognition and/or affect. This is achieved through a dialogue or conversation between an adult interviewer and a subject, which is centred around a problem or task. This task has been chosen to provide the subject with plenty of opportunity to display behaviour from which mental mechanisms used in thinking can be inferred. Several variations of the same task may be presented to probe the strength and limits of the theoretical construct perceived to underlie the subject's responses, and to give additional insights

into that subject's mental functioning (Hunting & Doig, 1991). Further description can be found in Hunting & Doig (1991) and Opper (1977).



THE MODEL

The process model diagrammatically displays the author's interpretation of the summative amalgamation of the issues perceived as pertinent to the development of a clinical interview protocol to assess children's understanding of probability. Many different interview protocols could evolve from the same background material, as there are many decisions to be made by the researcher during the process of development that will gradually determine the direction of the investigation. The model has been divided into two separate, but connected, phases which cater for the initial exploration of possible interview tasks, then the subsequent development of the more formal interview protocol.

The Hypotheses Generation Phase

The Hypothesis Generation Phase is an exploratory phase during which the research lacks specific focus. Several different aspects of Probability theory and Cognitive/Developmental theory may be represented in the initial Protocol to allow the researcher some experimentation with various approaches. This phase includes the trial of the chosen tasks on a selected population sample - possibly a small number of children from a particular age group. The skills of the interviewer and suitable recording techniques, such as video, audio and notes, may be developed during this time. The essential purpose of this phase is to clarify the focus of the research, and consequently produce an initial set of stimulus tasks for the interview. An explanation of each 'box' within the Hypothesis Generation Phase follows.

Probability Issues

1. *Theoretical Views of Probability*

There is still philosophical debate over the theoretical viewpoints which have been discussed by educational researchers such as Borovcnik & Kapadia (1991), Konold (1991), and Shaunessy (1992). A brief summary follows.

a)The *Classical* view involves the calculation of a probability prior to the event, expressed as a fraction, where the number of desired outcomes is placed over the number of possible equally likely outcomes.

b)Taking the *Frequentist* view the probability of an event is obtained from the observation of the frequency of particular outcomes during repeated trials. Theoretically, these trials are part of an infinite set of trials, so the actual experimental probability may not be exactly the same as the limit that the relative frequency tends towards.

c) The *Subjectivist* view does not perceive the probability as an inherent feature of the die and the rolling procedure (as do the two previous views), but rather sees the probability as a mental construct that may alter according to the information available. Although the ideas of symmetry

and frequency are still applied they may be overruled by subjective decisions. Therefore it is difficult to apply this view to logical problems.

When designing a research question or task on probability the decision must be made whether to steer the interviewee towards a particular viewpoint or to present tasks which are open to interpretation in various ways. In other words, is a prediction asked for, an experiment suggested or judgement requested ? In all cases the child's reasons would be sought.

2. *Misconceptions of Probability*

Some misconceptions of probability may just occur just because of lack of study of probability, but there is considerable recent evidence to suggest that some misconceptions are of a psychological nature (Shaughnessy, 1981). There has been an attempt to categorise the more systematic and predictable misconceptions. Kahneman and Tversky's (1972) put forward the theory that statistically naive people make estimates of probability using particular judgemental heuristics, such as 'representativeness' and 'availability'. The application of these heuristics can be supported by arguments that follow either 'Baconian' or 'Pascalian' reasoning (Cohen, 1979) and largely depend on whether a person believes the events involved are independent or not. These forms of reasoning can be related to the various philosophical viewpoints discussed above. Certain types of probability tasks may prompt children to respond using certain judgemental heuristics and certain types of reasoning. It must be decided by the researcher whether to employ or avoid these types of tasks.

3. R*andom Generators and Task Contexts*

Fundamental to the study of probability is the function of random generators, such as dice, spinners, packs of cards or blocks in urns. Several aspects of a random generator can be considered, such as the generator's physical characteristics (eg. colour, size, number of sides/sections/cards/blocks); and its symmetry (Is each possibility equally likely?). In the interview situation, will the generator be actually present, pictured or only described ? Who will have control of the generator, the child, the interviewer, or neither (as in the case of a computer) ? Consideration must also be given to differing cultural backgrounds when selecting interview materials and contexts for questions. For example, some children may have little or no home experience of games of chance involving dice or playing cards. The choice of random generators should be based not only on the mathematical properties of the material, but also on the level of experience the interviewees are likely to have had. Truran (1993) has been developing a classification system for probability tasks involving random generators which should prove to be quite useful when designing a set of questions for research, or for analysing previously used research tasks.

There is considerable concern among researchers and educators about the fact that even adults quite skilled in probability mathematics often do not apply this knowledge to real life situations, offering similar responses to naive people (Cohen, 1979; Konold, 1991; Shaunessy, 1981). Therefore, a change of context may produce a change in response to tasks that are mathematically the same. So, are the question contexts to be familiar or unfamiliar to the children ? Should the tasks be artificial (drawing blocks from a bag), be part of a game (rolling a die to move a marker) or set in a real-life context (random raindrop patterns) ?

4. *Language*

Language is another important consideration in question design, particularly when dealing with a large developmental range in children. Some key words, such as 'probability', 'likely', 'possible', 'chance' and 'random' produce a wide range of interpretations from children (and adults), few of which are mathematically correct (Konold, 1991; Truran, 1991). Even though many of these words are part of everyday language it appears that few children have a clear understanding of their meanings (Watson, 1993). Unless a purpose of the research is to explore the interpretations of such words, then perhaps they are best eliminated from tasks given to children. Apart from specific terminology, the language in which each task is presented obviously must be appropriate to the age level of each child.

Cognitive and Developmental Theories

1. *Piaget and Inhelder* (1951/1975) believed that their studies revealed a direct correlation between the formation of notions of probability and the formation of the different mathematical operations, and hence aligned various probabilistic understandings with their three developmental stages of Pre-operational, Concrete and Formal. Later research, such as Green (1982, 1989), has supported the idea of developmental stages, though not necessarily in agreement with the details of Piaget and Inhelder's findings.

2. *Constructivism.* Piaget's operational and structural analysis of the knowledge acquisition process has been identified as being consistent with, and representative of, the constructivist paradigm in cognitive psychology. Hunting (1983) provides a useful summary of the relevant literature and of the essential assumptions of constructivism.

3. *Fischbein* (1975, 1987) presents a somewhat different viewpoint of learning in his theories about children's intuitions of probability, combinatorial concepts and the influence of instruction on these intuitive notions of probability. According to Fischbein, intuition is a cognitive belief, which is immediate, holistic and obvious to the believer. Original *primary* intuitions can be modified or restructured as a result of instruction or experience to form a *secondary* intuition. Primary intuition may continue to exist alongside the newer secondary intuition which has been constructed to fit a particular context. Yet the secondary intuition may only be brought into play

for quite specific situations, and the person may revert to a primary intuition in other circumstances. This may offer a possible explanation for people's difficulty in applying probabilistic understandings to a variety of contexts.

4. *The SOLO Taxonomy*, which evolved out of dissatisfaction with some of Piaget's ideas (Biggs & Collis, 1982), provides a categorisation system that enables student responses to mathematical tasks and stimuli to be assessed. The Taxonomy presents five modes of functioning (Sensori Motor, Ikonic, Concrete-Symbolic, Formal and Post Formal), and differs from Piaget's theory in "the belief that persons can function in more than one mode, and that there are many opportunities for persons to use different modes to support learning in another mode" (Pegg, 1992, p369).

These cognitive and developmental theories are relevant to the process of designing a set of interview tasks on probability in that they provide part of the theoretical base for the research, may influence the interviewers direction of probing during the interview and have a bearing on interpretation of the children's responses. The level of the tasks needs to be appropriate to the expected approximate age/developmental stage of the children, yet be open enough to allow for possible operation at lower or higher stages.

Social/Cultural Contexts

Apart from the contextual factors already mentioned in regard to probability, there are also some more general factors to consider, such as: the child's expectations, the fact that the interviewer may be a stranger, the interview takes place in school so it might be seen as a test, and tasks tend to have right/wrong answers (Goldin, 1993). The school environment itself imposes certain expectations on the child's part during the interview. If previous experience of withdrawal from the class for a one-to-one encounter with a 'teacher' has involved testing or remediation, then the child is likely to bring the emotions and expectations attached to these experiences with them to the interview.

Recording Methods

Appropriate methods of recording the children's responses need to be explored. Video recording provides the most comprehensive method, but audio-taping, note-taking or checklists may also provide for the informational retrieval requirements.

Sample Population

The sample population selected for the trial of interview tasks naturally depends largely on the intended population for the finished interview protocol, which in turn is determined by the focus of the research.

The Theory Testing Phase

The *Theory Testing Phase* draws on the outcomes of the first phase to further refine the set of interview tasks. Issues of reliability and validity become important at this time, so each task must be thoroughly justified and include a list of anticipated responses (Ginsberg, Kossan, Schartz and Swanson, 1983). Before implementation, suitable methods of analysing the children's responses should be planned to ensure that the task response types and recording methods will provide the required information clearly.

Validity and Reliability Mechanisms

1. *Content Validity* can achieved by analysing proposed tasks in terms of the content stated to be appropriate for various age levels in prominent curriculum documents. Also, the proposed tasks could be submitted to a panel of appropriate mathematics education experts, who would be asked to consider "construct representation, relevance of task context, format of protocol, appropriateness of vocabulary, and adequacy of logical branches for tasks that have alternative pathways dependent on student responses "(Hunting & Doig, 1992, p.206).

2. *Theoretical Validity* can be achieved through providing a supporting rationale for each task that draws on mathematics education research literature, which would provide psychological and cognitive parameters not presented in curriculum documents.

3. *Process Analysis* "entails documenting typical student responses to each task type, with an interpretive commentary that attempts to link student behaviours to available theoretical constructs" (Hunting & Doig 1992, p.206). The required information would come from a trial of tasks with children and could coincide with the training of the interviewer/s.

4. *Utility*: If it is intended that the protocol be used by other investigators, then feedback on its *utility* and replicability would need to be sought.

Analysis Structures

Structures for analysing the children's responses should come from the theoretical foundation of the research (such as the SOLO Taxonomy), or be developed from the results of the Hypothesis Generation Phase (response categories), or perhaps evolve from a combination of sources. It is useful for the researcher to have pre-planned the analysis methods before finalising the interview protocol as this will often influence such factors as the task presentation style or the methods of recording employed.

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