STOCHASTICS, DIGITAL LEARNING OBJECTS AND THE PRIMARY CLASSROOM

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As part of the Australian national online curriculum initiative, The Learning Federation is developing hundreds of multimedia learning objects for use in schools. Some of these learning objects are designed to allow children to explore some basic concepts of probability and statistics, such as the relationships between random generators, sample spaces, likelihood of outcomes and both short and long run data on frequency of outcomes. This paper reports on the initial design development of these learning objects and on plans to research their use with children aged 6 to 12 years.

THE LEARNING FEDERATION

The Learning Federation is part of the *Australian Government's Schools Online Curriculum Content Initiative*, arising from the Australian Government as part of *Backing Australia's Ability: Innovation Action Plan* (2001) and is responsible to the Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA). It is an initiative with over 60 million dollars of funding from the Australian Federal and State/Territory governments, and New Zealand. The initiative aims, in the period from 2001 to 2006, to produce a broad range of high quality multi-media learning objects, covering a range of curriculum areas, to be delivered to all schools via the Internet. Each project draws together design teams consisting of education experts, multimedia developers, instructional designers and technical experts. The development is supported and monitored by Curriculum Area Reference Groups (representatives of education jurisdictions) and Expert Focus Groups (practising teachers).

The Learning Federation's definition of a learning object, shaped partly by the specifications of the proposed delivery mode, is as follows, "Learning objects are chunks of digital material - for example graphics, text, audio, animation, interactive tools - specifically designed to engage and motivate student learning" (The Learning Federation website, 2005). Four principles guide the development and quality assurance processes of all the projects: *learner focus* (developmentally appropriate and meaningful material for early years to Year 10), *integrity* (of content and pedagogy); *usability* (curriculum relevance and user engagement); and *accessibility* (compliance with standards, supportive of special needs, social inclusive). A further development guideline for the Mathematics and Numeracy projects is that the selection of mathematical content for learning objects must be restricted to concepts and processes that are difficult to teach or learn, that are poorly resourced or that can be presented in a very different way using the characteristics of the technology. In other words, the learning objects must not be replications of learning experiences that are already effectively provided by other means.

DEVELOPMENT OF PROBABILITY CONCEPTS

There is substantial agreement about the major characteristics of the development of probability concepts and associated strategies reported in relatively recent research. For example, the findings of Jones, Langrall, Thornton and Mogill (1997, 1999), Watson, Collis, and Moritz, (1997) and Way (1998, 2003a) are summarized in Table 1 below. In general, children as young as five or six years possess some intuitive notions of likelihood but react inconsistently to situations involving randomness. Gradually, separate concepts and supporting mathematical thinking develop (with or without instruction) until about the age of 8 or 9 years when children become very responsive to experiences or direct instruction that assist in the connection of probability concepts and in the development of proportional thinking. Integrated conceptual understanding and the ability to quantify probability in a range of situations follow, typically from about 11 or 12 years onwards.

Table 1: Developmental levels in probabilistic thinking as reported in three studies

Jones (Age range approx. 7-9 yrs) (1997, 1999)	*Watson* (Age range approx. 7-14 yr) (1997)	*Way* (Age range approx. 5-12 yrs) (1998, 2003)
Subjective • Limited probability judgments	*Prestructural* • No coherent use of relevant elements *Unistructural* • Concepts present in isolation	*Non-probabilistic Thinking* (Average age 5.8 yrs) • Minimal understanding of randomness • Reliance on visual comparison • Can't order likelihood
		Transitional phase
Transitional • Increased accuracy of judgments • Inconsistent reasoning • Beginning to quantify *Informal Quantitative* • More systematic approaches • Uses numbers informally to express probability	*Multistructural* • Several concepts applied, though in isolation or in linear fashion	*Emergent Probabilistic Thinking* (Average Age 9.2 yrs) • Recognition of sample space • Ordering through visual comparison or estimation • Addition and subtraction strategies for comparisons • Concepts of equal likelihood and impossibility
		Transitional phase
Numerical • Complete analysis of sample space • Assigns numerical probabilities in a range of situations	*Relational* • Integrated understanding of relationships	*Quantification of Probability* **(**Average Age 11.3 yrs) • Numerical comparison made • Doubling and halving strategies • Proportional thinking • Quantification emerging
	Extended Abstract	

VARIATION AND EXPECTATION

Watson (2005) and Watson and Kelly (2003) put forward quite a strong argument for taking a more global approach to the teaching and learning of probability and statistics through consideration of the major constructs of variation and expectation. Watson, Kelly, Callingham and Shaughnessy (2003) proposed four levels of development: prerequisites for variation, partial recognition of variation, applications of variation, and critical aspects of variation. They also observed an increasing ability to handle mathematical expectation, with proportional reasoning appearing only at the highest level. Research suggests that the development of understanding of variation and expectation from early childhood to the middle years follows progresses in the following order:

- Intuitive appreciation of variation as change or non-uniformity of outcome;
- Intuitive appreciation of expectation without the ability to associate it with mathematical theory (proportional reasoning or averages);
- Developing appreciation of appropriate variation in straightforward contexts (random generators and common physical phenomena such as height or weather);
- Ability to use qualitative terms to express expectation, such as 'more' or 'most';
- Slow development of ability to apply proportional reasoning to quantify expectation;
- Eventually the ability to tie together expectation and variation as integrated notions.

(Watson, 2005, p. 40)

Amongst the advice offered by Watson (2005) for curriculum and teaching is encouragement to move from discussions of non-mathematical contexts to "expectation with simple random generators where repeated experimentation can take place" and to "provide many repetitions of random experiments and other data collections to reinforce the juxtaposition of variation and expectation" (p.41).

THE ROLE OF TECHNOLOGY AND DESCRIBING LEARNER INTERACTION

Hoyles and Noss (2003, 2004) assert that certain types of interaction with computer technology can help learners "engage with, develop and articulate understandings of mathematical procedures, structures and relationships" (2004:1). They identify the type of software described as programmable 'microworlds' and expressive tools as being potentially effective in shaping mathematical learning (Hoyles and Noss, 2003). In these types of software the learner manipulates and creates 'objects' to explore various ideas and relationships. As would be expected, the nature of the learning is somewhat dependant of the tasks and activities. However, research suggests that the learning is highly sensitive to small changes in the technology and can be somewhat unpredictable. Therefore, a focus of research needs to be on carefully examining learners' interactions with the on-screen tools and modifying the software to further support learning. In this way, both the learner and the technology can change each other.

Of course, not all software provides the open-ended interaction opportunities as described above, and a comprehensive and useable framework for describing learner interaction has been somewhat elusive, with various researchers taking quite different approaches. Some researchers in the field of educational technology have developed sets of 'interactive constructs' to describe what learners 'do' (for example, Sims, 1997, 2000) which may provide a useful starting point for describing the types of the observable interactions that take place between the learner an the onscreen components of learning objects.

One way of describing design elements, and also the user's interaction with a learning object, is in terms of *multi-modal functioning,* which can be categorised as Visual/Spatial Mode, Linguistic Mode, Audio Mode and Gestural/Movement Mode (Way, 2003b, 2004). Each of these modes encompasses a range of onscreen components, such as, sounds, angle and perspective, absence or presence of words, sequencing of events.

Another way of considering design features is using the notions of conceptual models, 'affordances' and constraints present in learning objects (Norman, 1999). Harston (2003) suggests that affordances, which are characteristics of onscreen features that are useful to the user, can be cognitive, physical, sensory or functional. Such characteristics could be used analyse the design of learning objects and to help examine implications for learning in the technology interface.

PROBABILITY + LEARNING OBJECTS

Noticeably absent from research studies in the development of probability concepts is the situation where children are asked to create a sample space themselves to meet particular criteria. Way (1996) reported that activities that required the children to create sample spaces to meet various criteria are more likely to effectively stimulate probabilistic reasoning than activities merely requiring responses to pre-prepared sample spaces. Pratt and Noss (1998) and Pratt (1998, 2000) investigated children's reactions to computer software that presented them with simulations of a number of random generators, such as dice, cards, coins and spinners. Their purpose was to redesign the software to better enable the children to manipulate the 'gadgets' to explore probability concepts, and to investigate the learning that can take place through such interaction with random generators. Of particular importance has been the observation that new meanings for 'control' emerge in ways that support connections being made between aspects of the computer tools, such as dice, spinners, graphs and between the mathematical concepts represented, such as randomness and long-run data.

A particular set of learning objects being developed within The Learning Federation project focuses on 'chance and data.' The design brief was to create a series of small learning objects (no more than 1MB) to engage primary age (5 to 12 years) students in exploring the relationship between random generators (sample spaces) and the likelihood of particular outcomes occurring, as well as exploring frequency data. The technology is used to facilitate the construction of random generators, to quickly generate outcome data and to display it dynamically in a range of forms (statements, tables, graphs).

The design of these learning objects incorporates task structures and feedback on user actions, which are intended to scaffold learning. In all the learning objects, attention is given to the tensions between expectation and variation, as represented by visible sample spaces (random generators in the form of spinners) and the frequency data generated by trials (appearing in tables and graphs).

At the time of writing, a basic prototype of each learning object had been produced for trial with children and teachers, and the feedback received taken into account when beginning production. This paper focuses on one of the more open-ended learning objects, *Mystery Spinner*, and the plans to use it with children and study their interaction and learning. *Mystery Spinner* is considered to be ‘open-ended’ because of the opportunities given to the learners to create their own random generators and experiment with them. A brief description of the learning object follows. The screen shots (Figure 1) are from the prototypes so only present the basic functional elements of the learning object, rather than the final layout and appearance.

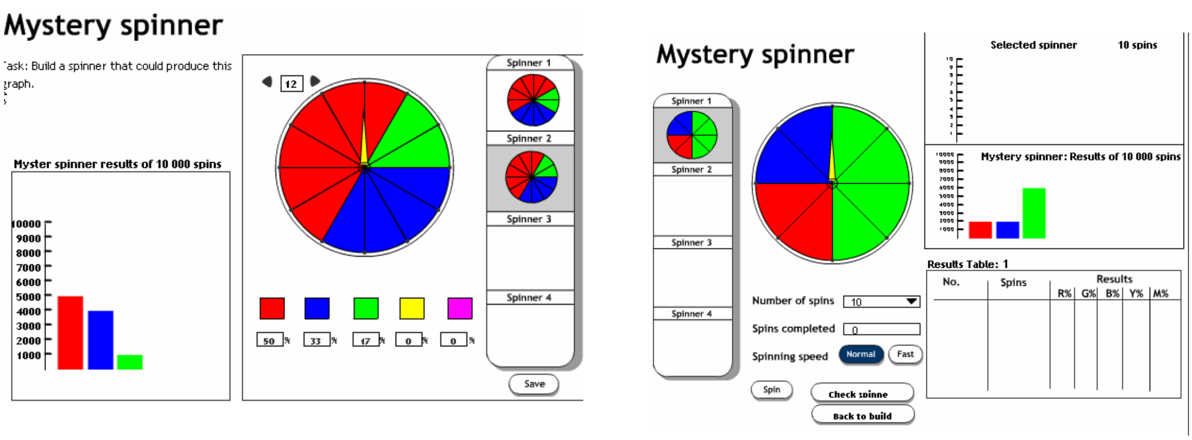

Figure 1: Screenshots of Mystery Spinner Prototype

Learning Object: Mystery Spinner

The intended learning outcomes for this particular learning object are:

- Order likelihood of events based on sample space information
- Order likelihood of events based on outcome data
- Explore the difference between the information provided by short, medium and long run data.

The intended mathematical processes include investigation strategies of:

- Representing and interpreting data (graphically)
- Observing regularities and differences
- Generalising and synthesising patterns and relationships
- Making, refining and extending conjectures.

Mystery Spinner presents the learner with a graph of frequency data produced by an undisclosed spinner and sets the challenge of creating a spinner to replicate the graph. A spinner construction tool is provided, as well as the facilities for running multiple trials from 10 to 10 000 spins. Data is recorded in a graph of the number times the pointer lands on each colour, and a table as percentages of the total number of spins. All of these elements are dynamically linked so the learner can watch the results build. The feedback given to the learners generally encourages them to make connections between the various sources of information (colour areas on the spinners, graph, table) and eventually reveals the mystery spinner.

PROPOSED RESEARCH PLAN

The purpose of the research is to investigate the ways in which children interact with and learn from the selected learning object. The expected outcomes include an assessment of the design features of the learning objects and a description of the children's interaction and learning. Therefore, the overarching research question is *Does the learning object promote the intended learning outcomes*? It is hoped that this information may contribute to the development of a framework for describing and assessing similar technology-based learning situations. There will be two major sources of information; the analysis of the learning object design and examination of children's interaction and learning.

Analysis Of Selected Learning Objects

The completed learning object will be thoroughly analysed in terms of the following aspects:

- Mathematical concepts and processes in relation to recent research on the development of probabilistic thinking;
- Design features of the learning objects, drawing on techniques described in previous research.

Answers to the following research questions will be sought from the analysis of information:

- Does the learning object have appropriate learning expectations for the intended age group?
- Do the design features appropriately represent the intended mathematical concepts and relationships?
- What is the most useful approach to describing design features in terms of the support offered to describing children's interactions and learning?

Case Studies With Children

The selected learning object will be used with children and the interaction observed and discussed with the participants, using the following questions as a guide:

- What sequence of actions do students choose?
- Which design features do they give priority to?
- What modifications do they make to spinners and what is the reasoning behind the changes?
- What relationships do they perceive between the spinner and the trial data?
- What relationships do they perceive between the expectation (theory) and actual outcome (experimental and variation)?
- What do the students believe they have learnt, and have the intended learning outcomes been achieved?

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