

**Conceptualization and Design of *Probability Explorer*:**  
**A Research-based Journey Towards Innovative Educational Software**

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## **Conceptualization and Design of *Probability Explorer*: A Research-based Journey Towards Innovative Educational Software**

The design of *Probability Explorer* was inspired by: 1) the lack of research-based elementary probability software; 2) constructivist principles for designing computer microworlds; and 3) research on children's probabilistic reasoning. Although commercial software exists, these applications do not typically provide an open-ended environment with research-based operations and tools appropriate for children to construct meanings for concepts of chance. Research on teaching and learning of probability has shown that students have intuitive notions about chance, some of which lead to difficulties in learning probability concepts. Children should be engaged in using their intuitive probabilistic ideas to design and simulate experiments, analyze data, construct understandings, and develop probabilistic reasoning skills. Although research has been done on children's learning of probability (e.g., Fishbein, 1975; Jones, Langrall, Thornton, & Mogill, 1997), investigating children's probabilistic reasoning with technology is a recent endeavor (Pratt, 1998; Drier, 2000).

### **Inspirational and Theoretical Basis for Design**

Based on a constructive process of re-presenting experiences, actions, or mental processes for developing mathematical knowledge, researchers have worked with children and shown that computer microworld environments can facilitate such a process. Papert (1980) originally used the term microworld to describe a self-contained world in which children "learn to transfer habits of exploration from their personal lives to the

formal domain of scientific construction” (p. 177). Battista (1998) believes that for a computer microworld to be “fertile” the environment should:

- 1) support problem-centered inquiry;
- 2) be based on research of students’ mathematical learning;
- 3) cultivate mental models of abstract ideas; and
- 4) induce reflection and abstraction.

The open-ended nature of a computer environment is critical in fostering appropriate and sustained learning experiences. Land and Hannafin (1996) state that open-ended learning environments such as microworlds should “support experiences for learners to identify, question, and test the limits of their intuitive beliefs” (p. 38).

### **Conceptualizing the *Probability Explorer* environment**

The overall goal in designing *Probability Explorer* was to create an open-ended environment for children to simulate interesting chance situations. Children can create experiments to model many typical textbook probability situations (e.g., coins, dice, bags of marbles), or they can design experiments of interest to them--whether they are playfully contrived or meant to model real world phenomenon (see figure 1).

INSERT FIGURE 1

By tapping into children’s intuitive notions of chance, *Probability Explorer* provides a wide array of tools to help develop understanding of probability concepts. Once randomly generated objects appear, a child can sort, “stack,” or “line up” the icons

in a playful and potentially meaningful manner (see figure 2). Actions on these objects can help the child instantiate the experimental results and analyze data by comparing quantities or observing the order in which results occurred. The ability to have moveable representations of randomly generated data substantially extends the capabilities of physical experimentation where results are usually only listed or tallied. In this regard, the microworld connects with a child's physical world and extends the potential actions available in this new mathematical "world."

#### INSERT FIGURE 2

One of the fundamental aspects of random phenomena is unpredictability in the short run, but predictability of an overall pattern in the long run (i.e., concepts of independence and the law of large numbers). To give children experiences with unpredictability of individual results and predictability of an overall pattern, *Probability Explorer* allows children to use graphs as both objects of display *after* a simulation is complete, and as objects of analysis *during* a simulation. During a simulation, children can use the graphs to visualize the wide variability in a distribution with a small number of trials and the stabilization of a distribution as the number of trials increase.

#### INSERT FIGURE 3

The microworld is also flexible enough to allow students to change the likelihood of an event and to explore unequivocal events. The ability to change the probability of

an event can help make connections between probability concepts, rational numbers, and proportional reasoning. This capability allows teachers and students to model real world phenomenon such as weather forecasts (e.g., 75% chance of rain). To maximize the learning potential, *Probability Explorer* allows users to view the numerical model of chance in three ways (see figure 4).

INSERT FIGURE 4

### **Iterative design process**

The design and development of *Probability Explorer* began in the Fall of 1998. Within a six-month period, the author was engaged in an intensive iterative design process involving research-based design, rapid prototyping, field-testing, and focused discussion groups (see figure 5). The second phase (9 months) of the development process was part of the author's dissertation research. A 1-week pilot study with 3 children resulted in redesign of several tools and addition of others (e.g., bag of marbles environment). An 8-week study with 3 different children was done concurrently with rapid design and development to meet the needs of the children during the study. A final comprehensive revision was completed after analysis of the children's work.

INSERT FIGURE 5

INSERT FIGURE 6

Further research needs to be conducted with children using *Probability Explorer* in a variety of small group and classroom situations in elementary and middle school. I agree with Roschelle and Jackiw (2000) who call for concurrent innovation in curricula, technology and pedagogy and urge technology designers to work as part of a team in researching and developing these innovations. I believe *Probability Explorer* could potentially impact the teaching and learning of probability in elementary and middle schools. To facilitate this widespread impact, it is imperative that future developments in the software are aligned with developments in school curricula and pedagogy and part of a team process with other researchers, technology designers, mathematics educators, and curriculum specialists. Such a project could transform the software through an iterative process and build a curriculum and educational support system to maximize the potential impact on children's probability understanding.

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## Figures

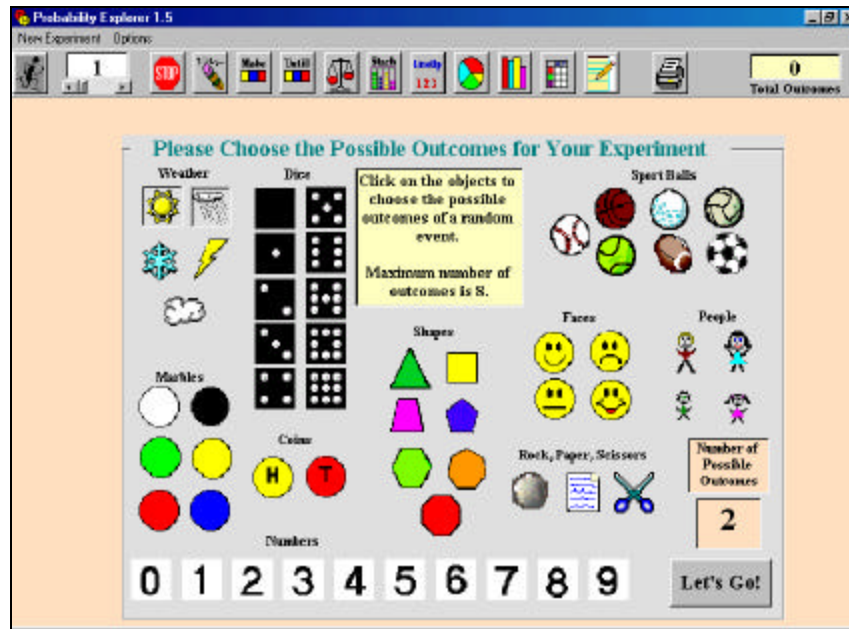


Figure 1. Choices available for designing experiments in *Probability Explorer*.

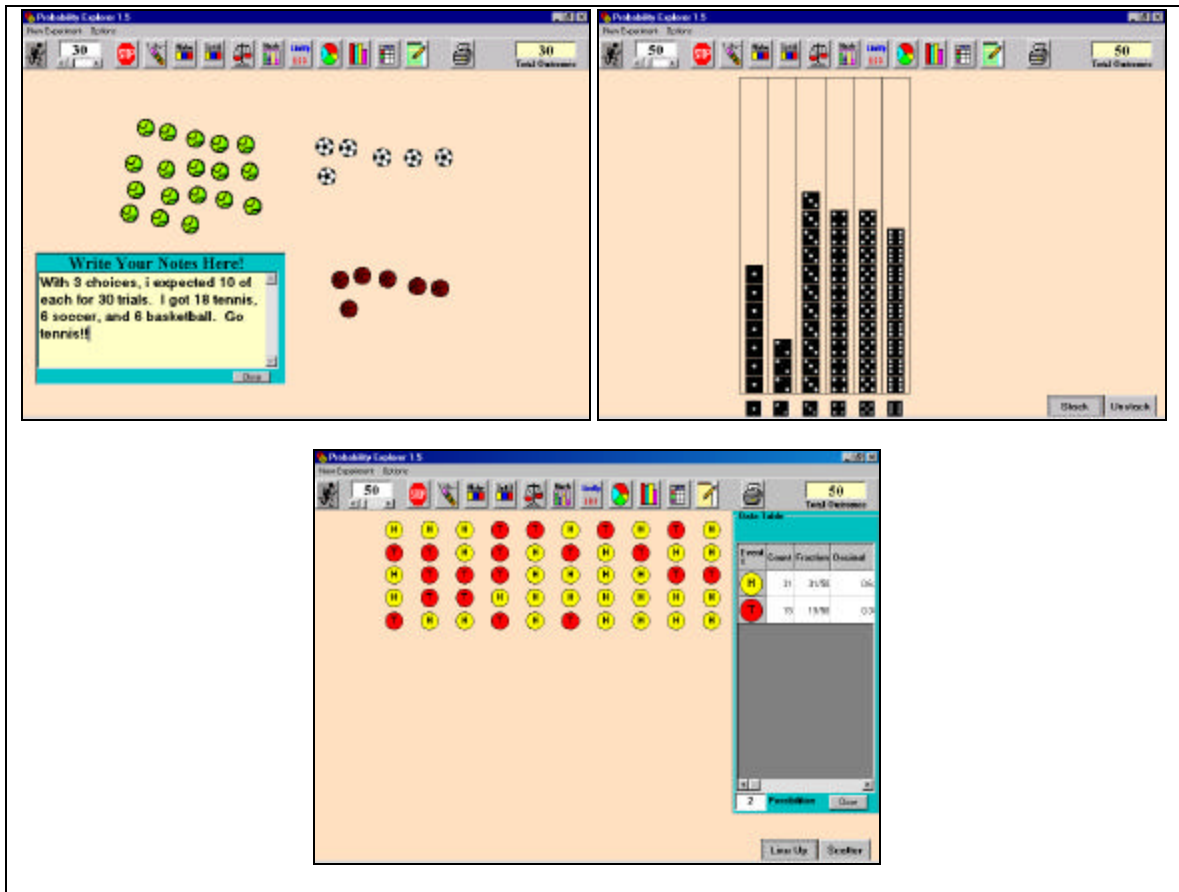


Figure 2. Data sorted, “stacked”, and “lined up” for multiple representations for analysis.

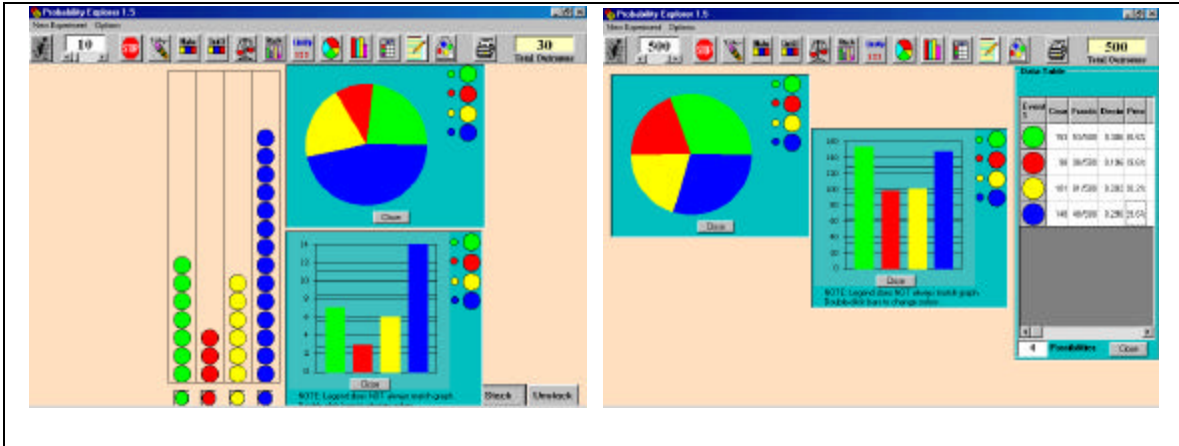


Figure 3. Graphs as objects of display (left) and objects of analysis (right) for a marble experiment with 3 green, 2 red, 2 yellow, and 3 blue marbles.

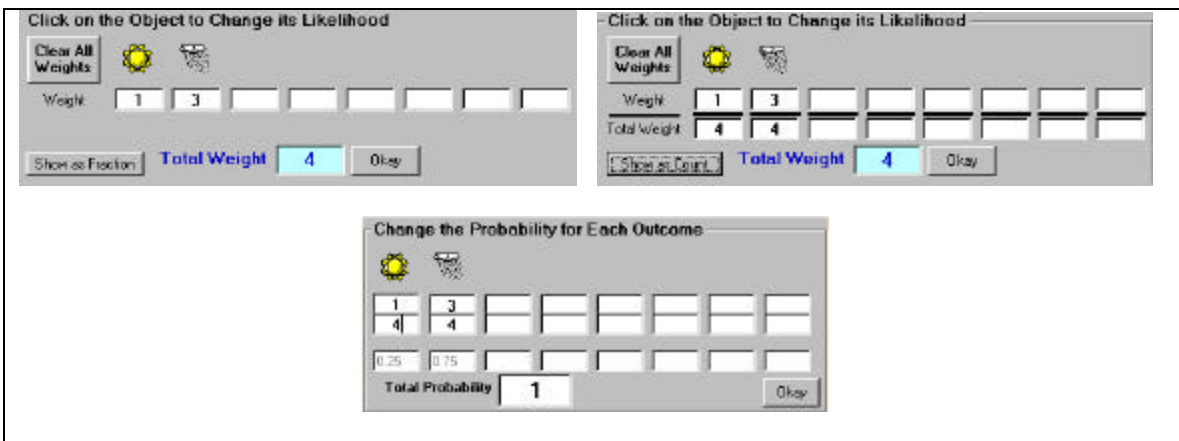


Figure 4. Three ways to display chances: a) as part-part (odds), b) as part-whole (probability), and c) using rational numbers and total probability of 1.

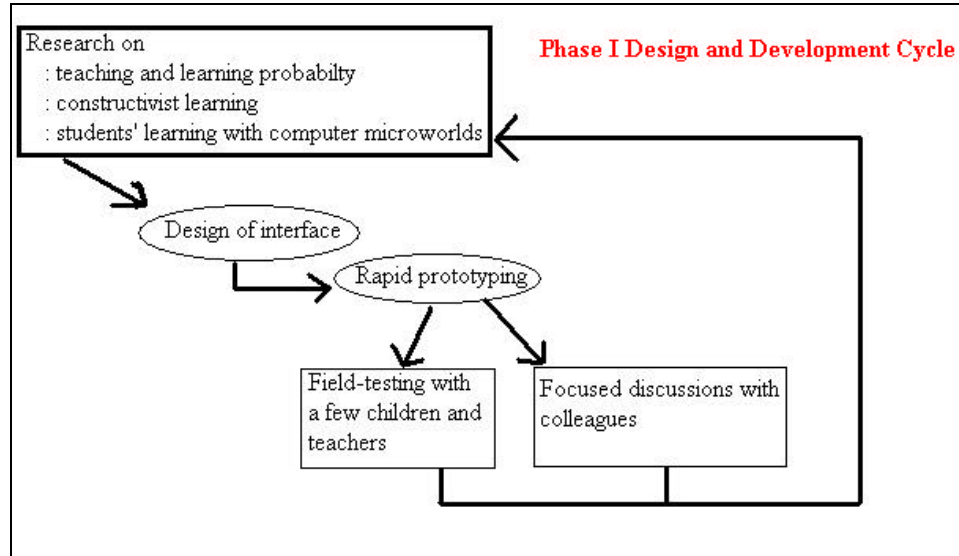


Figure 5. Phase I of design and development of *Probability Explorer*

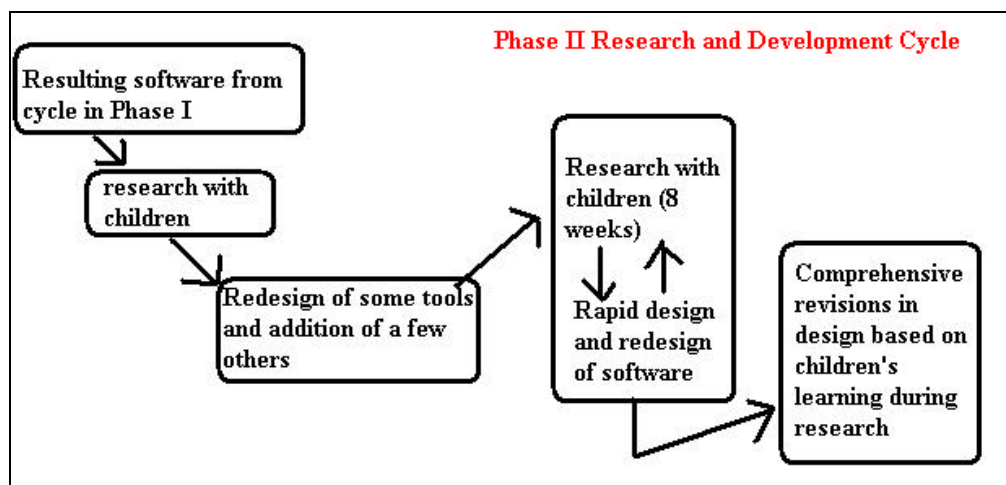


Figure 6. Phase II of design and development of *Probability Explorer*.