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ABSTRACT

HyperProb is a Hypercard tutoring system designed to help students develop an effective step-by-step schema for solving probability problems. With this program, students are able to select areas they wish to study via hypermedia links and develop an understanding of terminology and procedures at their own pace with continued reinforcement. Nine graduate students in counseling assisted in the HyperProb evaluation by using the tutor and attempting to solve seven probability programs. They then answered questions about their satisfaction with the content, pace, depth, and navigability of the program. Overall, students reported liking the self-paced nature of the tutor, but had difficulty linking to the next unit until after one was completed. Results indicated that most students felt it would be optimal to have a teacher available while using the tutor, rather than having HyperProb as a "stand alone" instructor. Researchers not only incorporated suggestions back into the program but also studied errors made on the seven problems to shed light on the program's possible weaknesses. A copy of the seven probability problems and a summary of common errors are appended. (BEW)

Formative Evaluation of the HyperProb Tutoring System for Probability Problem-Solving

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Introduction

HyperProb is a HyperCard tutoring system developed under the assumption that helping students develop an efficient schema for solving probability problems would improve their performance on such problems. Guiding people in the skills required to organize problem information accurately is important to the development of a reliable schema for problem-solving. To this end, we have developed a seven step model useful for organizing problem information and solution strategies. This model is reminiscent of Polya's four step "How to Solve It" strategy (Polya, 1957), and offers the student a convenient way to conceptualize the steps involved in working towards a successful solution of a probability problem. This 7-step model has been described in detail elsewhere (O'Connell, 1993a; O'Connell & Bol, 1995); only the seven steps are provided here:

1. *Understand the given information.*
2. *Identify what is being asked (the goal).*
3. *Develop notation for the given information and the goal statement.*
4. *Identify the correct sample space for the problem.*
5. *Select a method of solution.*
6. *Computing the solution.*
7. *Is the solution reasonable?*

A vast amount of research has documented the conceptual difficulties experienced by students during probability problem-solving (Hansen, McCann & Myers, 1985; Garfield and Ahlgren, 1988; Konold, et. al., 1993). While probability problem-solving certainly demands an appreciation for probability concepts, successful performance also requires an understanding of the terminology and procedures (equations, formulas, rules, and their inter-relationships) that are commonly used to represent these concepts. Through the HyperProb Tutor, students are able to develop this understanding at their own pace, and with continued reinforcement.

The primary tutoring capabilities of the HyperProb Tutor are shaped through the use of the 7-step model. As example problems are presented during the tutoring session, each of these seven steps is addressed. Further, students are encouraged to follow these seven steps when solving review problems. It is believed that through this process a greater understanding of probability concepts and procedures will result, subsequently leading to a stronger and more lasting ability to use and interpret probabilistic information normatively.

Description of the System

As recommended by other instructional design teams, we have utilized a multidisciplinary approach to the planning and design process of the HyperProb system, emphasizing different areas of expertise (Morrison & Ross, 1988). These areas include instructional design, evaluation, and experience in probability and statistics instruction.

The HyperCard system was chosen as the platform for the probability tutor, primarily due to the availability of Macintosh computers at most schools and colleges. HyperCard offers many advantages as an instructional tool, most specifically in its linking capabilities. Our software

offers students the ability to jump from unit to unit, based on their needs as well as to their responses to practice and test questions supplied throughout the program.

The system contains six instructional units. Each unit includes a review section and a summary card detailing the major points covered in the unit. The first four units focus on introductory information regarding probability, and the last two units incorporate our instructional model (the 7-step model described above). The content for each of the curricular units are:

1. Understanding Probability
2. Sample Spaces
3. Outcomes and Events
4. Equally Likely Events
5. Compound Events
6. Independence, Dependence and Conditional Probability

Through the linking capabilities of HyperCard, a student can choose which of the topics to be studied, and can review the summary cards for any of the units at any point in time. Question cards posed throughout the tutor include a "hint" and an "answer" button to provide the student with optional assistance. The student inputs their answer(s) to a question or a series of questions directly onto the card. For each unit, a monitoring system keeps track of all student entries and actions. This information can be printed out for review at the end of each student session.

A calculator button is included on each card, which will pop open the calculator when the button is clicked. A "rule card" button is also available for review of formulas. A variety of buttons and text fields are used throughout the tutor. Simple yes/no responses are usually handled through radio buttons. More sophisticated responses, either text or numerical, can be input directly by the student into well-defined areas on the cards. Currently, the system reads and evaluates their answers, and will prompt them for tutoring if the answer is incorrect. The monitoring system keeps track of all text entries as well as button actions.

Evaluation

The primary purpose of our project was to investigate the success of the seven step model as an aid in teaching and learning elementary probability concepts and procedures. Additionally, we wanted to ascertain how well the tutor actually provides the student with the knowledge and skills required for solving the types of problems typically encountered in a first course in probability and statistics. We utilized a four stage evaluation/development process: (1) repeated tutor content and curriculum review by the instructional designer and statistics instructor, (2) preliminary evaluations of each unit by 10 student volunteers, (3) incorporating the students' suggestions into the tutor and upgrading the monitoring system, and (4) evaluation of the entire system. In this paper, we report on the overall evaluation of the tutor. Our future plans include incorporating the use of the tutor into a formal statistics course.

Results

Our evaluation results are very encouraging. We solicited 9 students (four male and five female) to evaluate the tutor and the 7-step model. None of these students were currently taking a statistics course, although all but one reported having had at least one course in probability and statistics. Four of the students were at the Masters level in teaching or counseling, and five were Doctoral students in counseling psychology.

For the evaluation, we asked the students to complete the tutor, and then solve seven probability problems (Appendix A). A written introduction to the tutor was distributed, describing the units and the use of the help and hint buttons. During the tutor phase, students were able to ask questions about either content or the tutor capabilities, as we would expect this to occur during a regular classroom setting. During the test phase, we supplied the students with a summary card (from the tutor) giving a brief summary of the topics covered in each unit, a list of the 7-step model, and the summary rule-card (also developed through the tutor). Our

reasoning was to encourage thoughtful solution instead of relying on memorization of formulas or rules. After completing the test, the students were asked to fill out a short survey regarding their likes and dislikes about the HyperProb tutor.

Overall, students reported liking the self-paced nature of the tutor best. They enjoyed being able to go back and check their answers, and using the hint buttons and cards for help. One of the students, who teaches mathematics, wrote that the tutor "has major possibilities." The difficulty reported most frequently by these students involved linking to the next unit when a unit has been completed. We have improved this feature, as well as attended to some syntax and visual problems also identified through our evaluation. Several students suggested adding more practice problems at the end of the unit, however, we have not yet focused on this concern.

We asked students to report on a five-point scale about several specific aspects of the tutor: was it informative, easy to follow, were they comfortable with their ability to move through the tutor, etc. Means for each of these items are given below (there were no missing values). A score of 1 indicates strongly disagree, a score of 5 indicates strongly agree. As can be seen below, students were highly satisfied with both the tutor and the use of the 7-step model.

Item		Mean
1.	Overall, I felt that the tutor was informative.	4.3
2.	Too much material was covered for one sitting.	3.6
3.	Too little material was covered, or not in enough depth.	1.6
4.	I felt the tutor instruction was easy to understand.	4.1
5.	I felt comfortable with my ability to move through the tutor.	4.3
6.	I now have a good picture in mind of probability concepts.	4.1
7.	I felt that the 7-step model was useful in forming solutions to probability problems.	4.2
8.	After completing this tutor, I felt more knowledgeable about probability.	3.7
9.	Having the summary sheet, rule card, and 7-step model available was useful in solving the written problems.	4.1

Responses to five of the items on the 7-item post-test were compared to a random selection of 9 tests from a unit on probability given during a self-paced course at our university (University of Memphis). Responses to the last two items were compared with a random selection of 9 solutions contained in probability booklets which the first author has developed for use in her introductory statistics courses (the booklets are collected and students then work in groups on problems related to those in the booklet). Solutions were reviewed for accuracy and to detail the kinds of errors students made in their solution attempts. Errors were classified according to an error categorization scheme developed during previous research (O'Connell, 1993a; 1993b). This scheme describes the kinds of errors made in four broad categories: text comprehension, errors in probability concepts, errors in probability procedures during problem solving, and arithmetic errors. Appendix B lists the error classification scheme used during this evaluation (a more detailed appendix is available on request from the first author).

Table 1 reports the number of incorrect solutions for each of the 7 items on the tutor post-test. We also report the number of incorrect solutions on these items for the comparison samples. As can be seen in the table, none of the tutor students made any errors on the first five questions, compared with 6 incorrect solutions for students in the self-paced course. This may be due, in

part, to the fact that students in the self-paced course do not have information available to them when they complete a unit test. In comparison, the tutor students had the tutor summary card, rule card, and 7-step model available as they worked through these problems. However, these results are encouraging, and support further development of the tutor.

For items 6 and 7 on the post-test, the tutor students had more incorrect solutions than the comparison group. This comparison group completed the items while working through a booklet on probability problem-solving. This booklet did not use the 7-step model as a teaching tool, but did go through several problems which were isomorphic to both problems 6 and 7. Those students could have reviewed the solutions to these problems while working on the current ones. These two items, in addition, were of a more difficult nature than items given to the self-paced class.

In this situation, it is more informative to review the kinds of errors made by students on these two problems. This information indicates some areas where the tutor could be improved, and as such, is very valuable. Table 2 details the error comparison for test-items 6 and 7. For item 6, a difficult item involving understanding of inequality statements and complementary probabilities, the majority of the errors observed were text comprehension errors, involving difficulty understanding the inequality being asked for (T4). Several students also simply multiplied (using the rule for independent events), even though there was no information in the problem to suggest independence (P4). In comparison, the most common error made for the booklet comparison group was simply writing down the given information and not attempting to solve the problem (P2). Additionally, two students in this comparison group made up nonsensical rules and plugged in values, such as averaging the probability values given, or subtracting the two complementary values given in the problem. Even though students in the booklet group could review previous problems, many were still unable to begin a solution. For the tutor group, the difficulty was primarily dealing with the goal of the problem stated as an inequality, i.e., the probability of students being advanced in neither subject. This suggests an area of expansion for the tutor, which currently does not have many problems similar to item 6 asked on the post-test.

For item 7, we also see some interesting kinds of errors made during problem solving. These are described in the right half of table 2. Most of the students using the booklets were able to solve for the correct answer. Several students in the tutor group, however, had some difficulties. The most common error here, occurring twice, resulted from students reporting only the conditional probability to part (b) of the problem, instead of the conjunction. This may have resulted from remembering how the solution to a similar problem was presented in the tutor.

Discussion

Overall, this evaluation has provided us with some valuable information regarding student's acceptance of the tutor, and it's actual tutoring capabilities. Through this evaluation, several potential areas for improvement have been identified, and our intent is to use the information we have gained here to incorporate final revisions and modifications to the tutor. The next important step is to evaluate HyperProb's actual impact as part of classroom instruction in probability problem-solving.

The HyperProb tutor was developed with the idea of being an adjunct to classroom instruction, and similarly, most students felt that it would be optimal to have a teacher available while using the tutor, rather than have it used as a "stand alone" instructor. We do not envision our tutor taking the place of a classroom teacher for the topic of probability. Rather, we believe that our tutor, like those in other subject areas, could best be used to support the teacher's efforts in the classroom. This use of the HyperProb tutor would allow the teacher an opportunity to provide greater individualized instruction to specific students, an outcome of computer tutoring that is consistent with the findings of Schofield, Eurich-Fulcer, & Britt (1994).

Table 1
Number of Incorrect Solutions for Tutor and Comparison[a] Students on Tutor Post-test

Item No.	Tutor	Comparison
1.	0	1
2.	0	0
3.	0	2
4.	0	1
5.	0	2
6.	8	7
7.	5	2

[a] Comparison students for problems 1 through 5 were completing post-test in self-paced course for unit on probability. Comparison students for items 6 and 7 were completing in-class booklets from a unit on probability.

Table 2
Errors[a] for Comparison (Booklet) Students, Items 6 and 7

Student No.	Item 6		Item 7	
	Tutor	Booklets	Tutor	Booklets
1.	T7	P2	T2, C6	correct
2.	T7	A	correct	T1, T5
3.	T4, P4	P10	correct	correct
4.	T4, P4	P2	T5, T2	correct
5.	T7, T4	P2	P2	correct
6.	T4, P4	correct	correct	correct
7.	C6, correct	P2	P8	correct
8.	T4	correct	correct	T1
9.	T4, A	P10	X	correct

[a] Key to error codes:

T1: Assigning given values incorrectly
T2: Incorrect goal
T4: Misinterpretations of inequalities (including stating the goal of the problem)
T5: Selection with versus without replacement
T7: Incorrect model of situation given in the problem
P2: Incomplete/Unfinished (i.e., writing out the given information only)
P4: Procedural errors involving independence (i.e., assuming independence, unjustified)
P8: Procedural errors involving conditional probability
P10: Inventing incorrect procedures or rules
C6: Formal language of probability
A: Arithmetic errors
X: Unknown error

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Appendix A

Student Code _____

1. A patient suffering from a skin disease reads in a medical journal that of 15 people who had the same disease, 8 showed rapid remission while 7 recovered slowly. Based on this finding, what is the probability that the patient will show rapid remission?

2. The probability of an event occurring on any single trial is 1/2. What is the probability of its occurring on each of two independent trials?

3. a. What does it mean to say that two events A and B are mutually exclusive?
   b. Give an example of two mutually exclusive events.
   c. Give an example of two events which are <u>not</u> mutually exclusive.

4. a. What does it mean to say that two events A and B are independent?
   b. Give an example of two independent events.
   c. Give an example of two events which are <u>not</u> independent.

5. A teacher is giving individualized instruction to 9 students. She has been informed by the school psychologist that 2 of the students have low IQ's, 6 have average IQ's, and 1 has a high IQ. If she randomly selects a student to work with first, what is the probability that the student will be one who tested either low or average in IQ?

6. A school principal examined the records of last year's kindergarten classes. Out of all kindergarten pupils, a total of 24% were advanced in arithmetic, and 76% were not. 16% were advanced in reading, and 84% were not. Exactly 6% were advanced in both. What percentage of pupils were advanced in neither subject?

7. On a late night nursing shift, 7 of the nurses on a floor are full time RN's, 3 are part-time RN's, and 5 are student nurses. A physician on this floor requests the assistance of two of the nurses. Assuming that this selection is made at random, find the probability that:
   (a) the first nurse selected is a student nurse.
   (b) both of the nurses selected are student nurses.

Appendix B

Types of observed errors in probability problem-solving (from O'Connell, 1993b)

Text Comprehension Errors

Type	Label
T1	Assigning given values incorrectly (i.e., to a different event)
T2	Incorrect goal (when expressed as an equality)
T3	Choosing pairs instead of triples/singles, etc.
T4	Misinterpretations involving inequalities
T5	Selection with vs. without replacement
T6	Real world knowledge errors (i.e., about cards, dice, etc.)
T7	Incorrect model of situation or information given in the problem
T8	Interference from another (previous) problem

Conceptual Errors

Type	Label
C1	Misconceptions: defn. of probability/sample space/n(S)
C2	Misconceptions: frequency vs. probability
C3	$p>1.0$
C4	$p<0$
C5	$P(S)\neq 1.0$
C6	formal language of probability (i.e., $P(.3)+P(.4) = P(.7)$)
C7	Misconceptions: equally likely events
C8	Misconceptions: mutually exclusive events
C9	Misconceptions: independence
C10	Misconceptions: mutually exclusive vs. independence
C11	Misconceptions: complementary events

Procedural Errors

Type	Label
P1	Procedural errors in determining sample/event space
P2	Incomplete/unfinished
P3	General use of formulas
P4	Procedural errors involving independence
P5	Procedural errors involving mutual exclusiveness
P6	Procedural errors involving sequential experiments
P7	Procedural errors involving use of tabled data
P8	Procedural errors involving conditional probability
P9	Procedural errors involving complementary events
P10	Inventing incorrect procedures or rules

Arithmetic Errors

Type	Label
A	Arithmetic errors

Unclassified Errors

Type	Label
X	Unclassified errors